U.S. Army Corps of Engineers

New England District
Concord, Massachusetts

Phase II Engineering Evaluation of Contamination at the Former Naval Auxiliary Landing Field – Site 8 Charlestown, Rhode Island

Contract No. DACW33-94-D-0009

VOLUME I
REPORT

Delivery Order No. 0028
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13. ABSTRACT *(Maximum 200 words)*

Roy F. Weston, Inc. (WESTON) conducted a Phase II Engineering Evaluation of Contamination at the Former Naval Auxiliary Landing Field – Site 8, Charlestown, Rhode Island. The purpose was to investigate the extent of overburden soil and groundwater contamination in the vicinity of five former 25,000 gallon gasoline underground storage tanks; delineate the extent of light nonaqueous phase liquid (LNAPL) in the source area; evaluate remedial alternatives; and recommend the technology to remediate the site. Observations from borings, microwells, and monitor wells resulted in delineation of an area of LNAPL of approximately 4,400 ft^2 at the site. A measurable thickness of LNAPL was only observed in well CN13 (1.25 feet). Bedrock groundwater in the source area contained only a trace of xylene. Concentrations of organic compounds and lead detected in on-site soils do not exceed RIDEM criteria, and do not warrant remediation. LNAPL and dissolved benzene, ethylbenzene and lead in overburden groundwater exceed RIDEM GA criteria in the tank footprint area. Bioslurping was determined to be the most suitable method to remediate LNAPL at the site. Residual dissolved lead in the groundwater would be addressed through natural attenuation. A risk assessment is recommended to determine whether a significant risk to human health and the environment from lead in groundwater exists at the site. Residual and dissolved benzene and ethylbenzene in groundwater may be addressed by bioventing and air sparging to accelerate natural attenuation.

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13 February 2001

Mr. Albert Lemire
U.S. Army Corps of Engineers
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696 Virginia Road
Concord, Massachusetts 01742-2751

W.O. #10971.028.001.0019.02

RE: Response to Comments on the Draft Phase II Engineering Evaluation of Contamination at the Former Naval Auxiliary Landing Field – Site 8
Charlestown, Rhode Island.
DCN: NALF-020801-AAAK

Dear Mr. Lemire:

Roy F. Weston, Inc. (WESTON®) is pleased to present the following responses to comments for the April 1999 Draft Phase II Engineering Evaluation of Contamination at the Former Naval Auxiliary Landing Field – Site 8, Charlestown, Rhode Island.

WESTON received comments from the U.S. Army Corps of Engineers, New England District (CENAE) Project Manager on 12 September 2000. The responses to the comments from CENAE are detailed on the enclosed attachment. WESTON has incorporated these comments as noted, into the February 2001 Final Phase II Engineering Evaluation of Contamination Report.

Please feel free to contact me at (603) 656-5424 if you should have any questions.

Very truly yours,

ROY F. WESTON, INC.

Vincent DelloRusso

Vincent DelloRusso
Principal Project Scientist

VDR/dmv

Attachment

Response to Comments on the Draft Phase II Engineering Evaluation of Contamination at the Former Naval Auxiliary Landing Field – Site 8, Charlestown, Rhode Island.

REVIEWER: PHIL DURGIN

Comment #1: General - The report does not state what was stored in the five 25,000 gallon tanks. The implication is that it was gasoline since in Appendix A, Fig. 4-8 the title includes "gasoline storage area" and gasoline was found in CN13. However, one would think that avgas-type petroleum would also be at a site like this. It is an interesting site, tanks surrounded by lower permeability sediments that appear to have restricted flow and resulted in un-weathered gasoline more than 10 years old.

WESTON Response: *The type of fuel has not been specifically characterized by analysis. However, olfactory observations, groundwater results and simulated distillation results from the WESTON study are consistent with a leaded gasoline source. The text has been modified to indicate that gasoline was stored in the tanks. There is no additional information that would indicate whether this was for aircraft or land vehicle use.*

Comment #2: General – The investigation found that anaerobic biodegradation is active. My impression of the site is that bioventing/biosparging and skimming of product would be a favored alternative. Bioventing (pumping air to subsurface) may be preferable to SVE because 1) it is sure to drive the subsurface toward aerobic conditions that will promote biodegradation, particularly of benzene and ethylbenzene, 2) the aerobic conditions will stabilize the lead because lead will precipitate out under oxidizing conditions, 3) a major advantage of bioventing is the cost because there is no need for activated carbon with its associated disposal or regeneration costs, and 4) skimming of free product in CN13 (and possibly additional wells) is beneficial, particularly based on the RI regulations and RIDEM's concerns. This would be integrated with a natural attenuation approach that demonstrates the plume is not moving and that at the outer edge dissolved oxygen is biodegrading the benzene and ethylbenzene while stabilizing the lead. Please focus on the bioventing/biosparging and skimming option with a more in-depth evaluation of this alternative.

WESTON Response: *A thorough review of the remedial options was completed and concluded that bioslurping would be more applicable than the soil vapor extraction option proposed in the draft report. Bioventing/sparging and skimming options were also reevaluated. The report text has been significantly modified to reflect that bioslurping is the recommended alternative to remediate product while bioventing/sparging would be effective in accelerating natural attenuation of the dissolved groundwater plume. The rationale for this is clarified as follows:*

- *Bioventing will be effective in volatilizing some of the lighter components of the product, and biodegrading both the lighter and heavier components of the product at the interface between the product and the airspaces in the soil matrix. Bioventing attacks the product from the upper surface of the product layer, but cannot reach the majority of the product mass, and therefore cannot accelerate the biodegredation or* *volatilization of the product beneath the upper surface of the product layer. Air sparging, conducted in the groundwater below the product layer, would force bubbles of air up through the product layer, making contact with a larger percentage of the product mass than bioventing would. The effectiveness of the sparging would depend on the distribution and pathway of the bubbles, which is often difficult to control. Air sparging would remediate the product with the same mechanisms as bioventing, but because of the increased contact of the air with the product, the rate of remediation would be expected to be accelerated.*

- *An evaluation of the laboratory analysis conducted on a sample of the product (simulated distillation) indicates that approximately 64% of the product falls within the VPH range (carbon chain lengths up to 12) and approximately 36% falls within the EPH range (carbon chain lengths 12+). This indicates that 64% of the product would be amenable to volatilization by a process such as SVE or bioventing/air sparging. Most of the remaining 36% would be difficult to remove by volatilization – removal of this portion would be more amenable to biodegredation than volatilization. The rate of biodegredation would be limited by the availability of oxygen. Unless air was being sparged through the product layer, biodegredation would only occur on the surfaces of the product, where it was in contact with oxygen.*

- *The ability of air sparging to oxidize and precipitate out lead cannot be assumed. We do not have any information on the form or oxidative state of the lead. The pH, ORP, and the presence of other trace elements in the groundwater can greatly affect the solubility of lead. Even if the ORP of the groundwater could be raised enough by sparging to precipitate the lead, once the sparging was stopped, the ORP would likely return to background levels, and the Pb could return to the more soluble state. In addition, even if the lead was oxidized and in an insoluble form, it could still be adsorbed to micro particles that could still cause groundwater criteria to be exceeded. The best approach for dealing with the lead would probably to conduct a risk assessment and show that the risks due to lead are within acceptable limits.*

- *A mechanical process for removal of free product would speed up the cleanup of this site. Following removal of most of the free product, bioventing/sparging would be an appropriate and effective technology for removal of the residual product. Mechanical removal methods include skimming or bioslurping/multiple phase extraction. Bioslurping would remove the product and some of the most highly contaminated groundwater in the shortest amount of time. Skimming would be a much slower process since it relies on gravity flow of the product into the well, whereas bioslurping would "vacuum out" the soil pores. Both bioslurping and skimming would remove the volatile, semivolatile, and nonvolatile constituents in the* *product (VPH, EPH, and lead). Skimming would leave more residual product than bioslurping. However, product skimming would be significantly less expensive than bioslurping, and would likely be considered to be an acceptable method of remediation by RIDEM. Bioslurping works best in tight soils. The more permeable the soils, the less effective bioslurping is. The permeability of the soils at this site are at the upper limits of the applicability of the bioslurping technology.*

Comment #3: Page 3-9, Sec. 3.8 - The report states that the groundwater samples were analyzed unfiltered. On the previous page, there is mention of a low permeability formation and slightly cloudy discharge water despite considerable well development time. It would be appropriate to have a sentence that stated that turbidity was low in the samples, particularly since lead is commonly associated with clays and colloids. In addition, you later state (pg. 4-4) that the samples from the microwells did not represent the true concentrations of lead in ground water -- I assume that the well samples did. I see this is also addressed on pages 4-11 and 5-4.

WESTON Response: *Text has been added in Sections 4.2 and 4.4 to clarify the significance of the sample turbidity and the relative quality of the samples collected.*

Comment #4: Figure 4-6 - The northern end of the contour line by the pond has 5.50' and it should be 5.55'. There is an arrow northwest of CN13 that indicates ground water flowing to the northwest, however it appears to be flowing the other way in Fig. 4-5. There is not much evidence indicating water flowing to the northwest -- I wonder what the topography is like. Consider deleting the dashed 5.50 line, particularly if the topography goes up to the northwest.

WESTON Response: *The typo on Figure 4-6 has been corrected. A question mark has been added to the contour line at the northwest margin of the site to emphasize that the groundwater flow direction in this area is uncertain. Topography does go down slightly to the northwest and abruptly along the margin of the pond. The report text of Sections 4.5 and 5.4 explains that this is likely an area of groundwater stagnation. Measured groundwater flow directions at the site are variable due to the low horizontal gradient measured, and temporal changes in the water level in the pond and rainfall.*

Comment #5: Page 6-1, Sec. 6.1 - The evidence does not support groundwater contamination, particularly floating product, going under Little Nini Pond. The sheen may be from naturally-occurring organics

WESTON Response: *Text has been modified to indicate that the sheen may be naturally occurring. While groundwater flow data from this study does not indicate flow from the site toward the pond, historical pond level fluctuations, and a thick product layer on the water table could have allowed contamination to migrate toward the pond. It is also possible that sources* *other than the gasoline storage tanks may exist, such as a past spill. Based on the character of the sheen observed, a petroleum source could not be ruled out.*

Comment #6: Page 6-3, Sec. 6.3 - The remedial recommendations do not address the dissolved benzene issue. My understanding of the RI regulations is that they put considerable emphasis on removal of floating product and not just if there is a risk from lead. It is not clear what the level of effort would be for an SVE system. It would be helpful if the report provided a rough conceptual approach (i.e. is it one or ten SVE wells). While SVE can remove LNAPL and also oxygenate the subsurface, it does not seem to be the most cost effective approach especially if you agree with Table 6-1 that it would take 3-8 years for the remediation. It may take considerable time if free product must be removed from the fine grained sediments. The least expensive method of removing product is to remove that phase only -- and not to remove water also, as with bioslurping, and not to transfer it to the vapor phase as with SVE.

WESTON Response: *The dissolved benzene in the groundwater could be addressed with natural attenuation, once the free product source has been removed. Sparging would accelerate the biodegredation of the benzene, but an argument could be made for product removal followed by natural attenuation of the dissolved benzene. You are correct in noting that the treatment of water removed by bioslurping would result in a significant increase in costs over skimming or bioventing/sparging, However, it may be cost effective to lease a pre-assembled bioslurping system for several months during the spring/summer/fall, remove as much product as possible, ship the water and product off-site for disposal and follow-up with natural attenuation. The product removal phase would be much shorter with bioslurping than with skimming. The reduction in labor for product removal from an estimated 2 years to approximately 3 months combined with elimination of bioventing/sparging system may result in a more cost effective solution. Based on the limited area of product it is estimate that six wells or less could be needed to remediate LNAPL in the vicinity of well CN13.*

You are also correct in noting that SVE would result in higher costs than bioventing/sparging due to the need to treat the extracted vapor. Another limitation to SVE would be the fairly large percentage of product that falls in the EPH range and would most likely not be removed by volatilization. This portion of the product would need to be removed by biodegradation. SVE would be no more effective than bioventing, and probably less effective than sparging, at enhancing the biodegradation of the less volatile constituents. Lead would not be removed by SVE unless it was still in the organic form (tetraethyl lead or tetramethyl lead), which is unlikely due to the age of the spill.

To better evaluate the most cost-effective solution, conceptual designs and cost estimates could be prepared for a short-term bioslurping alternative and a longer term product skimming and *bioventing/sparging alternative. A risk assessment to evaluate the risks associated with the lead is also recommended.*

Comment #7: Appendix F - Some of the DO concentrations look too high -- like the decimal place is wrong.

WESTON Response: *Groundwater parameter data were reviewed. Field parameters were recorded from the wells on two occasions one week apart, although not every well was monitored during each event. Data from both events were added to the table for completeness. Based on overlapping measurements from several wells, it appears that the dissolved oxygen readings measured on 8 December1998 were not accurate, likely due to a malfunctioning probe. A note has been added to the table to indicate this.*

VOLUME I - REPORT

PHASE II ENGINEERING EVALUATION OF CONTAMINATION AT THE FORMER NAVAL AUXILIARY LANDING FIELD - SITE 8 CHARLESTOWN, RHODE ISLAND

Contract No. DACW33-94-D-0009
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Prepared for:

U.S. ARMY CORPS OF ENGINEERS
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February 2001

W.O. No. 10971.028.001.0019.02

VOLUME I - REPORT

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February 16, 2001
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15 Feb 01
Date

W.O. No. 10971.028.001.0019.02

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF APPENDICES

LIST OF FIGURES

Title **Page**

LIST OF TABLES

Title **Page**

LIST OF ACRONYMS

ADH	ADH Environmental, Inc.
ASTM	American Society for Testing and Materials
bgs	below ground surface
CENAE	U.S. Army Corps of Engineers, New England District
CERCLIS	Comprehensive Environmental Response Compensation and Liability Information System
cm/s	centimeters per second
DERP	Defense Environmental Restoration Program
DO	dissolved oxygen
DOD	Department of Defense
ft	foot, feet
ft/yr	feet/year
ft^2	square feet
FUDS	Formerly Used Defense Sites
gpm	gallon per minute
HPSPU	hydraulic powered soil probing unit
IDW	investigation-derived waste
IT	IT Corporation
LNAPL	light non-aqueous phase liquid
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligram per liter
msl	mean sea level
NALF	Naval Auxiliary Landing Field
NEB	New England Boring Contractors, Inc.
NTUs	nephelometric turbidity units
ORP	oxidation-reduction potential
OVM	organic vapor monitor
PID	photoionization detector
ppb	parts per billion
ppm	parts per million

LIST OF ACRONYMS
(continued)

PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RIDEM	Rhode Island Department of Environmental Management
RQD	Rock Quality Determination
RREL	Risk Reduction Engineering Laboratory
SMCL	secondary MCL
SOW	Scope of Work
SPLP-lead	simulated precipitation leaching procedure lead
SSHSP	Site Specific Health and Safety Plan
SVE	soil vapor extraction
SVOCs	semi-volatile organic compounds
TDB	Treatability Databases
TEL	tetraethyl lead
TPH-GRO	total petroleum hydrocarbons-gasoline range organics
UCL	Upper Concentration Limit
USEPA	U.S. Environmental Protection Agency
USGS	US Geological Survey
USTs	underground storage tanks
VISITT	Vendor Information System For Innovative Treatment Technologies
VOCs	volatile organic compounds
WESTON	Roy F. Weston, Inc.
WP	Work Plan
µg/L	micrograms per liter

SECTION 1

EXECUTIVE SUMMARY

1. EXECUTIVE SUMMARY

Roy F. Weston, Inc. (WESTON®) conducted a Phase II Engineering Evaluation of Contamination (Phase II Study) at the Former Naval Auxiliary Landing Field (NALF) – Site 8, Charlestown, Rhode Island. Field Investigations were conducted between October and December 1998. The purpose of the Phase II Study was to investigate the nature and extent of soil and groundwater contamination in the vicinity of five former 25,000 gallon gasoline underground storage tanks reportedly used to store gasoline at the site; identify the lateral extent of light non-aqueous phase liquid (LNAPL) in the source area; evaluate remedial alternatives; and recommend the technology to remediate the site.

A boring/microwell investigation was conducted on 12 to 13 October 1998 that included drilling eleven soil borings; installation of ten temporary microwells; monitoring for water/LNAPL levels; sampling and analysis of soil samples for volatile/semi-volatile organic compounds (VOCs, SVOCs), total petroleum hydrocarbons- gasoline range organics (TPH-GRO), total lead, and leachable lead; and analysis of groundwater samples for VOCs and total lead as part of the supplemental characterization of soil and groundwater contamination at the site. One LNAPL sample was collected for Simulated Distillation analysis to assist in evaluating remedial options.

Four overburden monitor wells, a bedrock monitor well, and a piezometer were installed during 9 to 12 November 1998. Hydraulic conductivity tests were conducted in new and existing wells. These wells were also monitored for water/LNAPL levels, and surveyed for elevation and location. Groundwater samples were collected from seven on-site wells for analysis of VOCs, total lead, and intrinsic bioremediation parameters. The piezometer was installed in Little Nini Pond for water level monitoring of surface water and groundwater in conjunction with nearby monitor wells.

Details of the methods employed during these activities are outlined in the Project Work Plan (WP) and Site Specific Health and Safety Plan (SSHSP) previously submitted to U.S. Army Corps of Engineers, New England District (CENAE) as part of this study.

Observations from borings, microwells, and monitor wells resulted in identification of an area of LNAPL of approximately 4,400 ft^2 in the vicinity of existing well CN13 in the western part of the former tank footprint area. A measurable thickness of LNAPL was only observed in well CN13 [1.25 feet (ft)]. An area of sheen was observed on groundwater surrounding the LNAPL plume encompassing an area of approximately 6,500 square feet ($ft^{2)}$. An area of sheen was observed on groundwater in the vicinity of well GSA4 in the southeastern part of the site. Analytical results are consistent with a leaded gasoline source derived from former on-site underground storage tanks (USTs) and/or associated piping. A sheen was observed on groundwater from the piezometer in Little Nini Pond; however, the source of the sheen is unknown.

Soil analytical results do not indicate concentrations of organic compounds or lead above Rhode Island Department of Environmental Management (RIDEM) direct exposure criteria or leachability criteria in the vadose zone or smear zone at the site. As a result, soil remediation is not warranted.

Groundwater samples revealed exceedances of RIDEM GA criteria for benzene, ethylbenzene, and lead in the immediate vicinity of the LNAPL plume. One exceedance for lead was detected in groundwater in the area of sheen at the southeastern part of the site. Overburden monitor well groundwater samples outside the LNAPL/sheen plume area did not detect exceedances of RIDEM GA criteria. Bedrock monitor well groundwater in the source area contained only a trace of xylene.

Analysis of intrinsic bioremediation parameters of groundwater from monitor wells revealed a decrease in oxidation-reduction potential (ORP) in the source area; an increase in ferrous iron and alkalinity concentrations in the source area; and a slight increase of sulfate concentration in the source area. These trends are indicative of anaerobic biodegradation. A lack of correlation was observed for dissolved oxygen and nitrate that are typically indicative of aerobic processes. These observations suggest that anaerobic biodegradation is the dominant active intrinsic bioremediation process at the site.

Water level data from microwells measured in October 1998 indicate an overburden groundwater flow direction toward the south-southeast with a horizontal gradient of about 0.02. Water level data from monitor wells and the piezometer in Little Nini Pond indicate an overburden groundwater flow direction toward the southwest with a hydraulic gradient of 0.001. A strong downward vertical gradient of about 0.4 is indicated between surface water and groundwater at the piezometer location in the pond. As a result, overburden groundwater in the immediate vicinity of the pond is interpreted to flow radially away from the pond. A comparison of interpreted groundwater flow patterns between microwell and monitor well data suggests that groundwater flow patterns are sensitive to seasonal rainfall variations.

Soil fill within the tank foot print area ranges from well-graded sand with gravel (SW) to poorly graded silty sand with gravel (SM) with silt concentrations from 5% to 30%. Undisturbed soil outside fill areas is generally silty fine sand with gravel. Bedrock beneath the site is coarse-grained, pink granite with abundant fractures. Overburden hydraulic conductivities determined from slug tests range from 1.4E-04 centimeters per second (cm/s) to 1.6E-02 cm/s with the highest values observed in areas of fill. These values were consistent with results of laboratory permeability tests. The bedrock hydraulic conductivity was estimated at 1.23E-02 cm/s. Seepage velocities values were estimated at 0.5 to1.6 feet/year (ft/yr) in silty fine sand soils and 29 to 53 ft/yr in sand and gravel fill soil.

Nine technologies for remediation of LNAPL and/or lead, including no action, were screened for applicability. Six of the nine technologies were evaluated to address site-specific contamination including product recovery pumps, soil vapor extraction (SVE), bioslurping, air sparging, adsorption, and no action (natural attenuation). Of these, bioslurping was determined to be the most suitable remedial technology for the site.

As a result of the investigations to date, the following general conclusions are made:

- LNAPL and dissolved concentrations of benzene, ethylbenzene and lead in overburden groundwater related to a release(s) of leaded gasoline exceed RIDEM GA criteria at the site, and are limited to the immediate vicinity of the tank footprint area.
- Bedrock groundwater has not been impacted at the site.

- Concentrations of organic compounds and lead detected in on-site soils do not exceed RIDEM direct exposure or leachability criteria, and therefore do not warrant remediation.

- Simulated distillation analysis results from the LNAPL indicated that apparently 64% of the product falls within the VOC range with the remaining 36% being heavier petroleum components.

- Bioslurping would be the best applicable technology to remediate LNAPL at the site because it is the most suitable technology to remediate all components of the LNAPL in a relatively short period of time. Product-phase lead would be removed in the LNAPL. Residual dissolved lead in the groundwater would be addressed through natural attenuation. Residual and dissolved petroleum hydrocarbons, including benzene, in groundwater may be addressed by bioventing and air sparging to accelerate natural attenuation.

- If significant risk from lead in groundwater exists, and if available data indicate that the dissolved lead in groundwater will not attenuate, then a more aggressive form of remediation may be employed such as groundwater extraction and treatment.

Data gaps exist regarding the nature and extent of contamination at the site. These gaps should be addressed prior to implementation of remediation at the site. The following recommendations for additional investigation are made:

- Evaluate dissolved lead concentrations in groundwater by resampling wells GSA3, GSA4, CN12 and CN13 for total and dissolved lead for use in evaluating the risk of lead in groundwater at the site.

- Collect a groundwater sample from the piezometer in Little Nini Pond for analysis of VOCs and dissolved lead to evaluate the potential source of the observed sheen.

- A risk assessment should be conducted to determine whether a significant risk to human health and the environment from lead in groundwater exists at the site.

If contamination related to the observed releases at Site 8 is found in groundwater from the piezometer in Little Nini Pond, sediment and surface water at the eastern margin of the pond will require additional evaluation. In addition, more focused sampling (Acid Volatile Sulfides/Simultaneously Extracted Metals) of the sediment may be needed to evaluate potential risk to environmental targets.

SECTION 2

GENERAL

2. GENERAL

2.1 INTRODUCTION

WESTON was contracted by CENAE to perform a Phase II Study of Site 8 at the former NALF in Charlestown, Rhode Island. The Site 8 Phase II study included the following activities:

- A review of historical information and previous environmental investigation reports and a site walkover
- Sampling of seven (7) Geoprobe borings and ten (10) temporary microwells
- Installation of four (4) overburden monitor wells, one (1) bedrock well, and one piezometer
- Groundwater sampling and analysis of temporary microwells and monitor wells
- In-situ permeability testing (slug testing) of monitor wells
- Water/light non-aqueous phase liquid (LNAPL) level monitoring
- Location and elevation survey of borings and wells

This Phase II Report describes the above field investigations performed at the NALF Site 8. Data collected from these investigations have been used to characterize and evaluate the extent of LNAPL and also to evaluate and recommend remediation options.

Project objectives and background information about the site are summarized in this section. Section 3 describes the methodology used to perform the field investigations. Section 4 presents analytical results. Section 5 contains an evaluation of the data and resulting conclusions. Section 6 presents an evaluation of remedial alternatives for the remediation of soil groundwater and LNAPL at the site. Section 7 contains conclusions from the investigations and recommendations for remedial action. Appendices A through G contain the WESTON Soil Boring, Microwell and Monitor Well Logs, Field Notes, the Contract Laboratory Analytical Data Packages, Slug Test Data, Elevation/Location Survey Data, Groundwater Field Screening Data and Investigation Derived Waste Manifest Package, respectively.

2.2 PROJECT OBJECTIVES

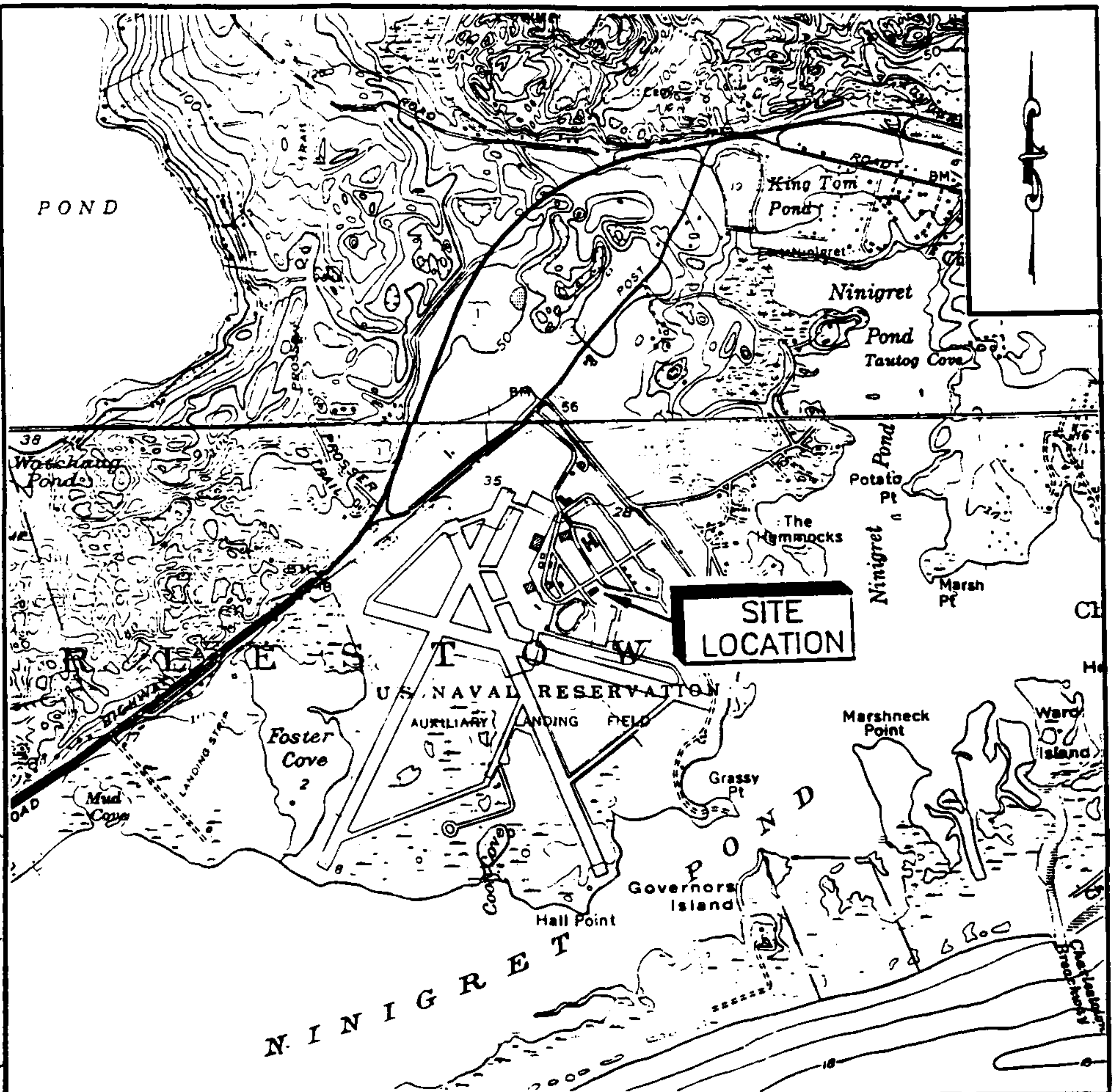
The Phase II study was intended to meet the requirements of the Scope of Work (SOW) prepared by CENAE and dated July 30, 1998. This SOW was implemented under the Defense Environmental Restoration Program (DERP) for Formerly Used Defense Sites (FUDS). The results of the Phase II field investigations (monitor well installation, groundwater and soil sampling, permeability testing, water level measurements, data evaluation, and technology screening) were intended to meet the project objectives. The project objectives, as specified in the SOW, were as follows:

- Investigate the nature and extent of soil and groundwater contamination in the vicinity of five former 25,000 gallon UST reportedly used to store gasoline at the site.
- Identify the lateral extent of LNAPL contamination and recommend the best technology to remediate the site.

CENAE developed the NALF Site 8 SOW in response to results from a previous Phase I study (IT, 1993) that detected LNAPL in an on-site monitor well, believed to be related to a release from a former UST reportedly used to store gasoline. A site history is provided in the section that follows.

2.3 SITE LOCATION AND SITE HISTORY

The Former NALF is located southeast of and adjacent to Route 1 in Charlestown, Rhode Island (Figure 2-1). The information in this subsection is based on information reported in the IT Phase I Study (1993) and observations by WESTON during the Phase II Study. The former NALF occupies 605 acres and is bordered on the south and east by Ninigret Pond (Figure 2-2). The western border of the NALF is Foster Cove. Site 8 is located within the boundaries of the former NALF to the northeast of Little Nini Pond. The Site 8 property is currently owned and operated by the Town of Charlestown and is open to the public for various recreational activities. The NALF lies within a GA as classified by the RIDEM.



BASE MAP IS A PORTION OF THE FOLLOWING U.S.G.S. 7.5 MINUTE QUADRANGLE:
QUONOCHONTAUG, RHODE ISLAND, 1975; AND CAROLINA, RHODE ISLAND, 1970 1:24,000

1 MILE 0.5 0 1

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

PHASE II ENGINEERING EVALUATION OF CONTAMINATION
FORMER NAVAL AUXIARY LANDING FIELD–SITE 8
CHARLESTOWN, RHODE ISLAND

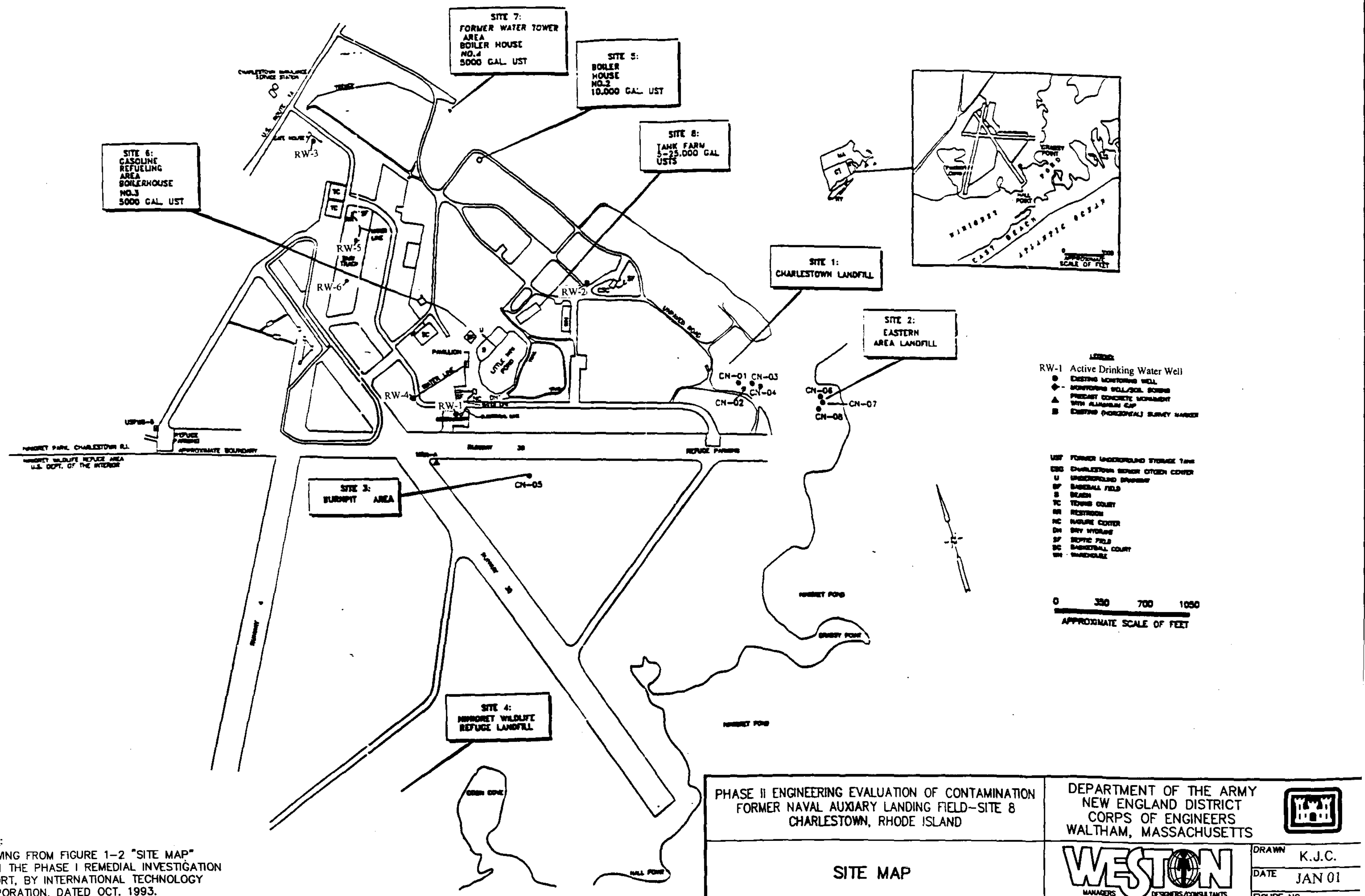
DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

LOCATION MAP

WESTON
MANAGERS DESIGNERS/CONSULTANTS
MANCHESTER NEW HAMPSHIRE

DRAWN	K.J.C.
DATE	MAR 98
FIGURE NO.	2-1

FILE NAME: G:\DESIGN\DWG\ACOE\CHRLSTWN\FIG1-1.DWG (PLOT 1=10)



NOTE:
DRAWING FROM FIGURE 1-2 "SITE MAP" FROM THE PHASE I REMEDIAL INVESTIGATION REPORT, BY INTERNATIONAL TECHNOLOGY CORPORATION, DATED OCT. 1993.

PHASE II ENGINEERING EVALUATION OF CONTAMINATION
FORMER NAVAL AUXIARY LANDING FIELD-SITE 8
CHARLESTOWN, RHODE ISLAND

DEPARTMENT OF THE ARMY
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WALTHAM, MASSACHUSETTS

SITE MAP

WESTON
MANAGERS DESIGNERS/CONSULTANTS
MANCHESTER NEW HAMPSHIRE

DRAWN	K.J.C.
DATE	JAN 01
FIGURE NO.	2-2

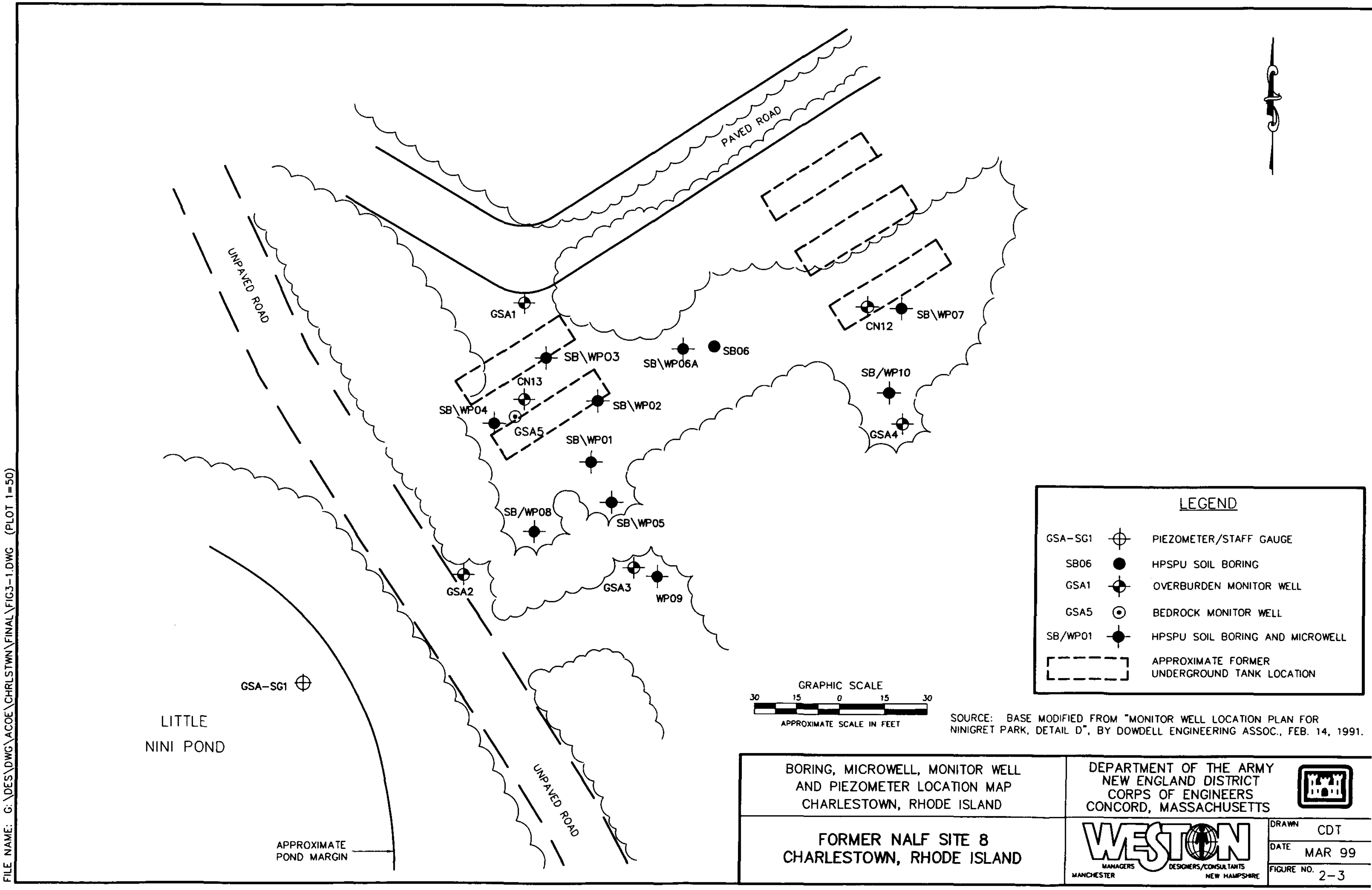
FILE NAME: G:\DESIGN\DWG\ACOE\CHRLSTWN\FIG1-2.DWG (PLOT 1=1)

The Former NALF was active from approximately 1940 to 1973. Five 25,000 gallon gasoline USTs reportedly used to store gasoline, located at Site 8 served as a major source of fuel for the former NALF during this period. These tanks were removed in the late 1980s. Site 8 and the NALF Landfill are identified in the U.S. Environmental Protection Agency's (USEPA) Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS) as site RI987480910.

The Site 8 tank area footprint is an open grassy area approximately 200 ft by 65 ft in size including the locations of five former gasoline USTs, surrounded by dense vegetation (Figure 2-3). The water table at Site 8 has been observed at a depth between approximately 13 to 16 ft. Depth to bedrock based on auger refusals and geophysical data is approximately 25 ft. The overburden soil is largely poorly sorted sand and gravel with cobbles and boulders. A lens of glacial till has been mapped in the Site 8 area. Site 8 is within 100 ft of Little Nini Pond. Six active drinking water wells exist at the former NALF. Site 8 is within 500 ft of the nearest drinking water well (RW–2; Figure 2-2). Little Nini Pond is a manmade fire pond, apparently receiving storm water from a broad network of drains across the former NALF. The site is within an active public recreational use area. Within the past year, a portion of a frisbee golf course was constructed over the site.

2.4 PREVIOUS INVESTIGATIONS

A Phase I Remedial Investigation Report for the former NALF was prepared by IT Corporation (IT) in 1993. As part of the Phase I investigation, IT drilled borings at two locations (locations CN12 and CN13), to a depth of 25 ft and installed two monitor wells at these locations (Figure 2-3). Soil and groundwater samples were analyzed from borings and wells, respectively. A surface water sample (SW-01) was collected from the adjacent Little Nini Pond. Groundwater samples were also collected from five on-site water supply wells (RW-1 to RW-5; Figure 2-2). In addition, IT conducted a Hydropunch soil gas and groundwater survey in the source area at Site 8, including the on-site analysis of seven soil gas samples and nine groundwater samples. Summary tables of analytical results, and maps from the IT study are included in Appendix A. During the Phase I investigation, several feet of LNAPL were observed in monitor well CN13



FILE NAME: G:\DES\DWG\ACOE\CHRLSTWN\FINAL\FIG3-1.DWG (PLOT 1=50)

located in the tank area footprint. The LNAPL was characterized as unweathered leaded gasoline based on laboratory analysis. The hydropunch water/soil gas study identified area of LNAPL encompassing approximately 1,000 ft^2 in the vicinity of well CN13. In addition, detected concentrations of benzene, xylenes, naphthalene and lead in the groundwater exceeded State of Rhode Island GA groundwater criteria. Groundwater flow was interpreted by IT to be to the southeast, away from Little Nini Pond, based on water elevations in wells across the NALF.

SECTION 3

SITE INVESTIGATIONS

3. SITE INVESTIGATIONS

3.1 INTRODUCTION

This Phase II report summarizes activities conducted by WESTON between September and December 1998. Field investigations performed at the NALF Site 8 include the installation of 10 microwells, sampling and analysis of groundwater samples collected from the microwells, sampling and analysis of soil samples collected from seven soil borings advanced at the former UST footprint area, installation of four overburden wells and one bedrock well, the sampling and analysis of groundwater samples collected from the five newly installed wells and two existing wells, slug testing of the new wells and one existing well, surveying investigation points, and the off-site disposal of investigation derived wastes.

The data collected from the Phase II field investigations were used to make recommendations as to the best available technology to apply for the remediation of soil and groundwater contamination at the site. Recommendations for remediation at the NALF Site 8 are presented in Section 7.

3.2 EXPLORATIONS

An overview of field explorations conducted as part of the Phase II study is provided below.

Microwells: Ten temporary microwells were installed at the NALF Site 8 on 12 to 13 October 1998 by ADH Environmental, Inc. (ADH). The rationale for the installation of the microwells was presented in the Project Work Plan prepared by WESTON, and dated 26 June 1998. The purpose of the microwell groundwater survey was to gain information on the extent of LNAPL, the extent of a dissolved contaminant plume in the subsurface and to aid in selection of monitor well locations. Water and LNAPL levels were measured in each of the microwells. Samples of groundwater were collected and analyzed for VOCs and lead. A summary of microwell survey results are presented in Section 4.

Soil Borings: Seven soil borings were advanced and sampled by ADH on 12 to 13 October 1998, under the supervision of a WESTON geologist. The methodology and rationale for the soil borings was provided in the Project Work Plan prepared by WESTON, and dated 26 June 1998. The purpose of the soil borings was to assess residual soil contamination at the former locations of on-site USTs. Soil samples were collected from each soil boring and submitted to an off-site analytical laboratory for analysis of VOCs, SVOCs, TPH-GRO, total lead and simulated precipitation leaching procedure lead (SPLP-lead). Grain size analyses and air and water permeability analyses were performed on soil samples from selected locations.

Monitor wells: Four overburden monitor wells and one bedrock well were installed during 9 to 12 November 1998, by New England Boring Contractors, Inc. (NEB) under supervision of a WESTON geologist. The methodology for the well installations was provided in the Project WP prepared by WESTON, and dated 26 June 1998. The rationale for the locations of the monitor wells was based on the results of the microwell and soil boring investigations. Three overburden monitor wells were located downgradient of the LNAPL plume, one overburden well was located upgradient of the LNAPL plume and the bedrock well was paired with overburden well CN13 within the source area plume. Soil samples were not collected from monitor well borings for chemical analysis.

Piezometer: A piezometer was driven into the bottom of Little Nini Pond at the eastern margin, to monitor groundwater and surface water levels in conjunction with nearby monitor well groundwater elevations. The methodology for the piezometer installation was provided in the Project Work Plan prepared by WESTON, and dated 26 June 1998.

Permeability Tests: Following installation and development of the monitor wells, falling head and rising head slug tests were conducted on the five new wells and one existing well (CN12) to estimate overburden and bedrock hydraulic conductivity.

Water/LNAPL Level Measurements: Groundwater levels and LNAPL levels (where present) were measured in each of the five newly installed monitor wells, two existing monitor wells at the site, and the piezometer in Little Nini Pond. These data were used to evaluate groundwater flow conditions at the site and are discussed in Section 5.

Groundwater Sampling: One round of groundwater samples was collected from the five newly installed monitor wells and two existing wells on 2 and 8 December 1998. Water level measurements and field parameters were recorded during the sampling event. Samples were analyzed for VOCs, lead, and intrinsic bioremediation parameters including alkalinity, nitrate, sulfate, ferrous iron, dissolved oxygen, and ORP. Details of the methodology were provided in the Project WP.

Field Surveying: Location and elevation data for microwells, soil borings, piezometer and monitor wells were collected during a survey conducted in December 1998. Data was collected relative to the State plane coordinate system and mean sea level (NGVD 1929) based on monuments at the NALF and survey coordinates provided in the Phase I Report (IT, 1993).

3.3 MICROWELLS

Ten microwells were installed by ADH on 12 and 13 October 1998, using a truck-mounted hydraulic powered soil probing unit (HPSPU) to evaluate the horizontal extent of LNAPL and characterize groundwater in the source area.

Soil boring/microwell locations are shown on Figure 2-3. Actual locations were modified only slightly from those proposed in the Project Work Plan. Microwell locations are denoted as WP01 to WP10 on Figure 2-3. Seven microwell locations were located within the footprint area of the former USTs. Three microwell locations denoted as WP08 to WP10 were located downgradient of the source area to characterize dissolved contaminant migration beyond the source area. Microwells were installed within boreholes advanced using stainless steel rods with a 2.5-inch diameter pointed tip or macrosampler. Microwells were constructed of 1.25-inch inside diameter schedule 40 polyvinyl chloride (PVC) with 10-slot screen. A five or ten ft screen interval was placed from approximately 10 to 20 ft below ground surface (bgs) in order to intercept the groundwater table and any LNAPL that may be present. Specifications for each microwell along with soil and water table information are shown on boring/microwell logs in Appendix B. A solid riser extended from the top of the screen to approximately one foot above the ground surface.

Each microwell was allowed to stabilize for a minimum of one hour or overnight prior to collection of groundwater samples and measurement of product and water levels with a bailer and electronic water level probe. Prior to purging the microwells, a bailer was slowly lowered into the microwell and observed for the presence of a sheen or product. LNAPL and groundwater level measurements were recorded in a field logbook and are presented in Section 4.

Groundwater was purged from each microwell using a bailer. An attempt was made to purge the microwells with a peristaltic pump; however, this method was ineffective due to the low yield of the wells. Microwells were purged until dry several times prior to the collection of groundwater samples. Groundwater samples were collected using dedicated ¾-inch diameter disposable teflon bailers.

Sample handling, decontamination and documentation were conducted as outlined in the Project WP. Groundwater samples were screened following the jar headspace method with an organic vapor monitor (OVM) with a photoionization detector (PID). One sample and quality assurance/quality control (QA/QC) samples were collected from each microwell for off-site analysis of VOCs and lead by Katahdin Analytical Services, Inc. Analytical results were validated according to procedures outlined in the Project WP. Sample analytical results are summarized in Section 4. Laboratory analytical reports are included in Appendix C-3.

After the completion of monitoring and sampling activities, microwells were manually removed from the subsurface. Each borehole was backfilled with a soil/granular bentonite mixture and sealed at the surface with granular bentionite. Microwells were located via taped measurements from fixed site features and identified on the ground surface with pin flags to facilitate the subsequent location and elevation field survey.

3.4 HPSPU SOIL BORINGS

Ten soil borings were advanced by ADH on 12 and 13 October 1998, using a truck-mounted HPSPU to characterize soil conditions in the source area. Soil boring locations are shown on Figure 2-3. Actual locations were modified only slightly from those proposed in the Project WP.

Boring locations are denoted as SB01 to SB10 on Figure 2-3. The boring locations are identical to the locations described for microwells above.

An additional boring SB06A was offset from boring SB06 due to a shallow refusal at location SB06. Analytical samples were collected from seven locations (SB01 to SB07; including location SB06, not SB06A) within the footprint area of the former USTs. Three boring locations, SB08, SB09 and SB10, located downgradient of the source area were drilled for the purpose of installing microwells. Soil samples were described and field screened but no analytical samples were collected from borings SB08 to SB10. Soil samples were collected continuously over the length of the boring by driving 1.5-inch inner diameter macrosamplers with dedicated clear plastic liners four ft long and were characterized following ASTM method D2488-93 by a WESTON geologist. Boring logs are provided in Appendix B. Samples were screened for organic vapors with a Thermo Environmental Instruments Model 580B OVM/PID. The presence of odor, stain or LNAPL was also noted. Soil samples were field screened by sliding the tip of a PID inside the longitudinally sliced sample tube. The borings were advanced to approximately 20 ft bgs or refusal, whichever occurred first. Borings had depths ranging from 15 to 22 ft with continuous sampling.

Two soil samples were collected from each of borings SB01 to SB04 for off-site chemical analysis. One sample was collected from the smear zone, and one sample was collected from the vadose zone above the smear zone. The soil samples were collected from discrete intervals, not composited, and were selected from the sample interval with the highest PID screening reading, in addition to the presence of any staining or odor. Soil samples were analyzed for VOCs (EPA Method 8260B), TPH-GRO (EPA Method 8015 modified), total lead (EPA Method 6010). Samples for VOC and TPH analysis were methanol preserved. Four smear zone soil samples were analyzed for SVOCs (EPA Method 8270C). In addition, three soil samples were selected for SPLP analysis for lead (EPA Method 1312). Two of the SPLP lead samples were collected from the vadose zone and one sample was collected from the smear zone. SPLP lead results were used for correlation of total lead results and comparison with State of Rhode Island criteria as discussed in Section 4.

One soil sample was collected from each of borings SB05 to SB07 from the interval with the highest observed contamination indicated by PID screening within the boring. These soil samples were analyzed for VOCs (EPA Method 8260B), TPH-GRO (Method 8015 modified), and total lead (EPA Method 6010), including appropriate QA/QC samples. Additional soil samples were collected for the geotechnical parameters air permeability, water permeability, unsaturated zone grain size, and saturated zone grain size. Two samples for each parameter were collected from separate borings in the source area. Soil samples for testing of air and water permeability were collected as undisturbed samples by capping the ends of the plastic macrosampler liner.

3.5 MONITOR WELL INSTALLATION

Four overburden monitor wells (GSA1 to GSA4) and one bedrock well (GSA5) were installed by NEB on 9 to 13 November 1998, using a Mobile Drill truck-mounted drilling rig with standard hollow-stem auger drilling techniques. The methodology and specifications for the well installations, including well development, are provided in the Project WP. Well construction logs including soil and rock characterization data are provided in Appendix B. The well locations were selected based on the results of the microwell groundwater survey and soil boring investigations as presented in Section 4.

The locations of five new monitor wells are shown on Figure 2-3. Monitor well locations GSA2, 3, and 4 were selected as downgradient groundwater monitoring points to evaluate the extent of dissolved plume migration beyond the limits of the UST footprint area. Location GSA1 was selected in an upgradient location to evaluate site background conditions and provide groundwater flow data on the north side of the footprint area. Bedrock well GSA5 was located as a well pair to existing well CN13 in the source area, to examine the vertical extent of the dissolved plume and the vertical groundwater flow gradient.

Soil samples were collected from the five monitor well locations using a 2-ft long by 2-inch outside diameter split-spoon sampler driven by a free-falling 140 pound hammer. Monitor well borings were advanced to a depth of 20 ft bgs with one split-spoon sample taken every five ft. Soil samples from each interval were field screened using an OVM/PID and described by a WESTON geologist in the same manner as for HPSPU borings described in Section 3.4.

The bedrock interval of well GSA5 was cored and described by a WESTON geologist. The maximum reading from each interval was recorded in the boring log along with observations for the presence of odor, staining or LNAPL. PID screening results for HPSPU soil boring and monitor well locations are summarized in Section 4. No soil samples were collected for chemical analysis from monitor well locations.

New and existing overburden and bedrock monitor wells were developed by the surge and overpump method using a submersible pump to remove fines from the wells. Well development was performed for a maximum of four hours per well or until the discharge water ran clear. Wells GSA1, GSA2, and GSA3 displayed low yields [<1 gallon per minute (gpm)] due to small saturated intervals and a low permeability formation. Although discharge volume and clarity improved during development, the discharge water remained slightly cloudy. Field parameters including pH, temperature, conductivity, ORP, dissolved oxygen (DO), turbidity, and organic vapor concentrations of groundwater were obtained during groundwater sampling. Purge water was field screened with a handheld PID and handled in a manner similar to other investigation derived wastes as described in Section 4.9 of the Project WP. Well CN13 was bailed repeatedly by hand until the product thickness was reduced to less than 1-inch. Approximately 20 gallons of LNAPL and water were purged from well CN13 and contained for off-site disposal.

3.6 PIEZOMETER INSTALLATION

One piezometer was installed along the east margin of Little Nini Pond for the purpose of evaluating the relationship between surface water and groundwater flow at the site. The piezometer was a small diameter (1¼-inch) galvanized steel riser with a 3 ft screen interval and a threaded top cap. The piezometer was driven into the pond bottom approximately 5 ft using a sledgehammer, so that the top of the screen remained approximately 2 ft below the pond bottom. Water levels were measured inside the piezometer and pond levels were measured outside the piezometer, referenced to the top of the casing.

3.7 LNAPL AND GROUNDWATER LEVEL MONITORING

On 2, 8, and 9 December 1998, WESTON recorded water and LNAPL level measurements from five new monitor wells, one piezometer, and two existing monitor wells at the site. Water and LNAPL levels were measured using an electronic oil/water/air interface probe or electronic water level probe graduated to 0.01 ft. The date, time, and depth to water and LNAPL, if present, measured from the innermost casing were recorded from each well. Surveyed casing elevations were subsequently used to convert the depth measurements to water level elevations relative to mean sea level (NGVD 1929).

Additional water level elevation data were tabulated from measurements recorded during the microwell groundwater survey on 13 October 1998. Groundwater and LNAPL levels were recorded in ten temporary microwells and two existing monitor wells at the site. Measurements were made from the top of the microwell casing using an electronic oil/water/air interface probe graduated to 0.01 ft. The length of the microwell casing above ground surface (stickup) was measured to 0.01 ft at the time of the survey. Surveyed ground surface elevations were subsequently used to convert the depth measurements to water level elevations relative to mean sea level (NGVD 1929).

Water level data recorded during this investigation and available historical water level elevation data from existing wells at the site were reviewed to determine the highest and lowest recorded water level elevations for each monitor well at the site. These data are used to evaluate water table fluctuations at the site, and are presented in Section 4 and discussed in Section 5.

3.8 GROUNDWATER SAMPLING AND ANALYSIS

On December 2 and 8, 1998, groundwater samples were collected from five new monitor wells at the site (GSA1 to GSA5) and two existing wells (CN12 and CN13). Wells were sampled using the USEPA low flow sampling procedure as described in the Project WP. The parameters pH, temperature, specific conductance, turbidity, ORP, DO and total VOCs (via PID) were measured. Seven groundwater samples were collected plus a duplicate sample, and a triplicate/QA sample for each analyte. Equipment rinsate and trip blank samples were also collected and submitted for analysis. Samples were analyzed for VOCs, total lead, alkalinity, nitrate, sulfate, and ferrous iron except for the trip blank that was analyzed for VOCs only. Samples were analyzed unfiltered. Sampling and analysis procedures and methods were performed as described in the Project WP. Analytical results were validated by a WESTON chemist according to procedures summarized in the Project WP. Groundwater sample analytical and data validation reports are presented as Appendix C. Results are discussed in Sections 4 and 5.

3.9 PERMEABILITY TESTING

Fifteen slug tests were performed by WESTON on five new monitor wells (GSA1 to GSA5) and one existing well (CN12) on December 9, 1998 to evaluate the hydraulic conductivity of the overburden and bedrock at the site. Multiple rising head and falling head tests were conducted on each well by introducing a 5 ft long, 1-inch diameter solid PVC blank (slug) into the well (falling head test) and subsequently removing the slug (rising head test). A 3-inch diameter slug was used in the bedrock well. Changes in the water level elevation in the well during the test were recorded by a programmable transducer (TROLL by InSitu) that was fully submerged in the well. This transducer is capable of measuring water level fluctuations at logarithmic and linear time intervals over the test duration.

Time/water level data was directly downloaded to a laptop computer and processed using the software AQTESOLV. This software follows the Bouwer and Rice (1976) method to determine hydraulic conductivity from the test data. The Bouwer and Rice method is valid for unconfined or semiconfined aquifer conditions. Slug test data are included in Appendix D.

3.10 FIELD SURVEY

In December 1998, investigation points and cultural features at the site were surveyed by Louis Federici and Associates, a Rhode Island licensed surveyor. Points were surveyed relative to the Rhode Island state plane coordinate system horizontal datum to +/- 1 ft, and to mean sea level (msl) vertical datum (NGVD 1929) to +/- 0.01 ft. The survey included determining the location and ground surface elevation of 10 microwell/HPSPU boring locations (SB/WP01 to 10) and location and inner casing elevation of five new monitor wells (GSA1 to GSA5), one piezometer, and two existing wells (CN12 and CN13), and the location of on-site cultural features including the roadway centerline and edge of pavement adjacent to the site. The results of the field survey are contained in Appendix E.

SECTION 4

ANALYTICAL RESULTS

4. ANALYTICAL RESULTS

4.1 INTRODUCTION

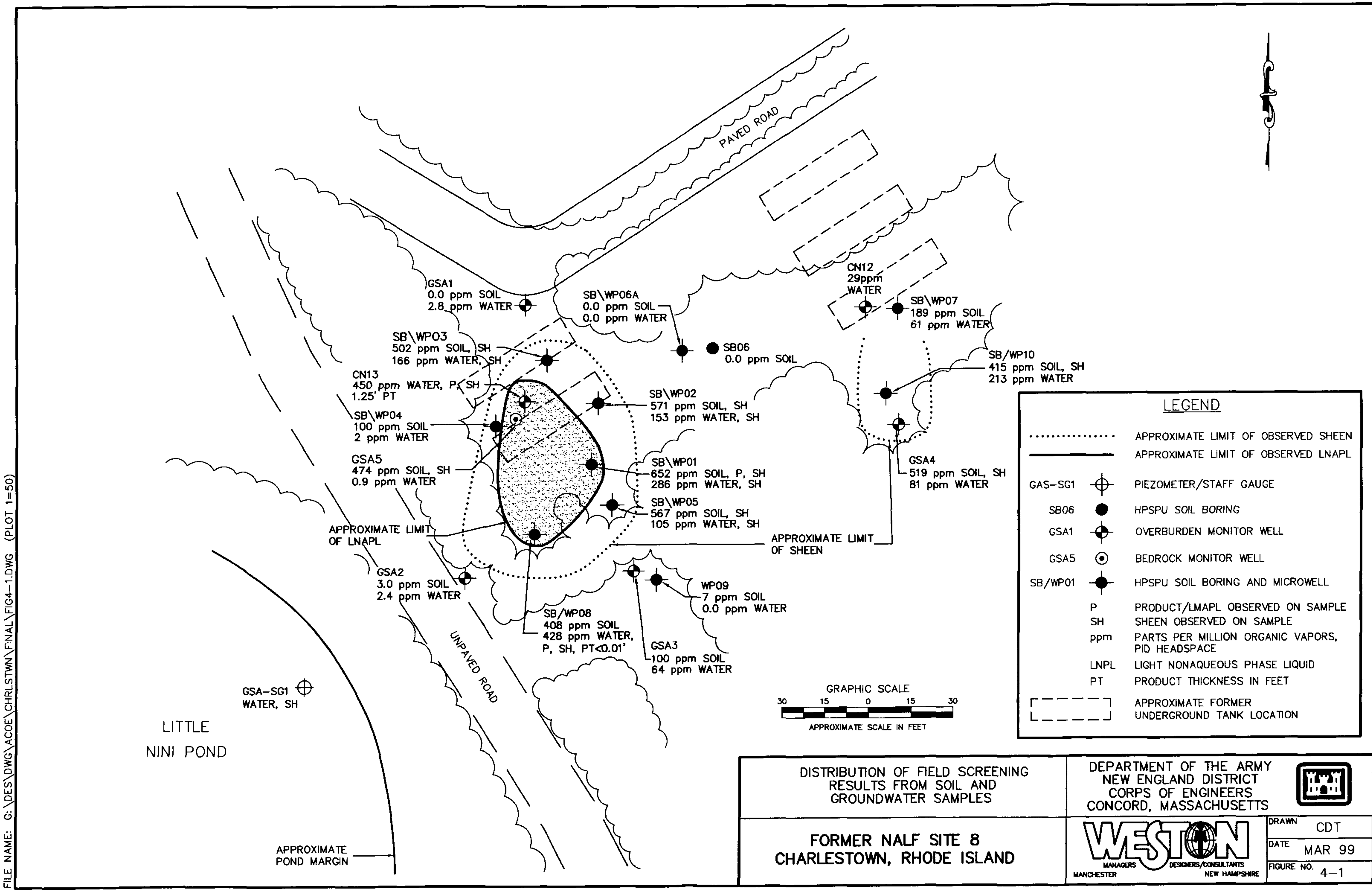
The results of field screening, analytical sampling, and monitoring of soil and groundwater at the site as part of this investigation are summarized below.

The analytical data generated as part of the HPSPU boring and microwell survey consists of on-site screening of soil and groundwater samples via handheld PID from eleven borings and ten microwells. One groundwater sample was collected from each microwell and submitted to the contract laboratory. Soil samples were collected from seven soil borings within the tank footprint area and submitted to the contract laboratory. Soils were characterized according to American Society for Testing and Materials (ASTM) Method D2488-93, and observations of staining, odor, or the presence of product in samples was noted. The presence of odor, sheen, or product in groundwater samples was also noted. Product and water levels were recorded in microwells prior to sample collection.

Soil samples were not collected for off-site analysis during the installation and sampling of five monitor wells at the site. Soil samples were field screened via handheld PID. Groundwater samples, including QC samples, were collected from each new monitor well and two existing monitor wells and submitted to the contract laboratory for analysis. Water and LNAPL levels, where present, were recorded in new and existing monitor wells. Rising and falling head permeability tests were conducted on each new well to evaluate the hydraulic conductivity of the overburden at the site.

4.2 MICROWELL GROUNDWATER SAMPLES

Groundwater samples were collected from microwells for analysis of VOCs and total lead as described in Section 3.3. Samples were field screening using the jar headspace method and an OVM/PID. Results of field screening are summarized on Figure 4-1. Samples were analyzed off-site by Katahdin Analytical Services. Validated analytical results are summarized in Table 4-1.



DISTRIBUTION OF FIELD SCREENING RESULTS FROM SOIL AND GROUNDWATER SAMPLES

FORMER NALF SITE 8
CHARLESTOWN, RHODE ISLAND

FILE NAME: G:\DES\DWG\ACOE\CHRLSTWN\FINAL\FIG4-1.DWG (PLOT 1=50)

Table 4-1

Summary of Microwell Groundwater Analytical Results for VOCs and Total Lead for Samples Collected By WESTON on October 13, 1998 at the Former NALF-Site 8 Charlestown, Rhode Island

Parameter	Units	RIDEM GA Criteria	H001-1098	H101-1098	H003-1098	H004-1098	H005-1098	H006A-1098	H007-1098	H008-1098	H009-1098	H010-1098	H201-1098	TB-2
VOCs														
Benzene	ug/L	5	7J^{2}	4J^{2}	37	27	2J^{2}	1U	1U	12J^{2}	1U	13J^{2}	1U	1U
Toluene	ug/L	1,000	1U	1U	3J^{2}	3	1U	1U	3	1UJ^{2}	1U	5UJ^{2}	1U	1U
Ethylbenzene	ug/L	700	390	370	100	9	14J^{2}	1U	82	6J^{2}	1U	5UJ^{2}	1U	1U
Isopropylbenzene	ug/L	NE	650	570	190	36	64	1U	1,600J^{3}	90J^{2}	1U	190J^{2}	1U	1U
N-Propylbenzene	ug/L	NE	140J^{2}	94J^{2}	32	5U	16J^{2}	1U	59	15J^{2}	1U	46J^{2}	1U	1U
1,3,5-Trimethylbenzene	ug/L	NE	310	260	160	6	36J^{2}	1U	300J^{3}	19J^{2}	1U	140J^{2}	1U	1U
Tert-Butylbenzene	ug/L	NE	10J^{2}	6J^{2}	1U	5U	1U	1U	9	1UJ^{2}	1U	5UJ^{2}	1U	1U
Sec-Butylbenzene	ug/L	NE	1U	10J^{2}	1U	5U	1U	1U	8	1UJ^{2}	1U	5UJ^{2}	1U	1U
P-Isopropyltoluene	ug/L	NE	6J^{2}	3J	1U	5	1U	1U	25	4J	1U	4J	1U	1U
N-Butylbenzene	ug/L	NE	20J^{2}	1U	1U	5U	1U	1U	5U	1UJ^{2}	1U	5UJ^{2}	1U	1U
1,2,4-Trimethylbenzene	ug/L	NE	610	520	300	13	11J^{2}	1U	530J^{3}	6J^{2}	1U	67J^{2}	1U	1U
Naphthalene	ug/L	20	8J^{2}	8J^{2}	2J^{2}	5U	1U	1U	5U	1UJ^{2}	1U	5UJ^{2}	1U	1U
2-Butanone	ug/L	NE	5U	5U	3J	4J	5J^{2}	3J	5U	5UJ^{2}	3J	5J^{2}	5U	5U
Chloroform	ug/L	NE	1U	5U	1U	1U	1U	1U	0.6J	1UJ^{2}	1U	1U	1U	1U
Chloroethane	ug/L	NE	1J	5U	2U	2U	2U	2U	2U	2UJ^{2}	2U	2U	1U	2U
1,1-Dichloroethene	ug/L	NE	0.6J	5U	1U	1U	1U	1U	1U	1UJ^{2}	1U	1U	1U	1U
Tetrachloroethene	ug/L	5	0.8J	5U	1U	1U	1U	1U	1U	1UJ^{2}	1U	1U	1U	1U
Carbon Disulfide	ug/L	NE	0.8J	5U	3J	2	5U	5U	5U	0.6J	1U	0.9J	5U	5U
M+P-Xylene	ug/L	10,000	1700	1600	580	34	8J^{2}	1U	390	1UJ^{2}	1U	5UJ^{2}	0.6J	1U
O-Xylene	ug/L	10,000	1U	9J^{2}	1U	1U	1U	1U	3J	1UJ^{2}	1U	5UJ^{2}	1U	1U
Metals														
Total Lead* See Note Below	ug/L	15	336	416	622	NA	1240	78.1	470	690	1060	850	1.8U^{2}	5.1

Shaded results exceeded RIDEM GA Criteria.

*NOTE: Samples for total lead were observed to be turbid and were analyzed unfiltered.

Due to insufficient yeld, a VOC sample was not collected from location WP02(H002); and lead samples were not collected from locations WP02 and WP04.

Samples for VOCs extracted by EPA Method 5030B and analyzed per EPA Method 8260B.

Samples for total lead extracted by EPA Method 3010 and analyzed per EPA Method 6010B.

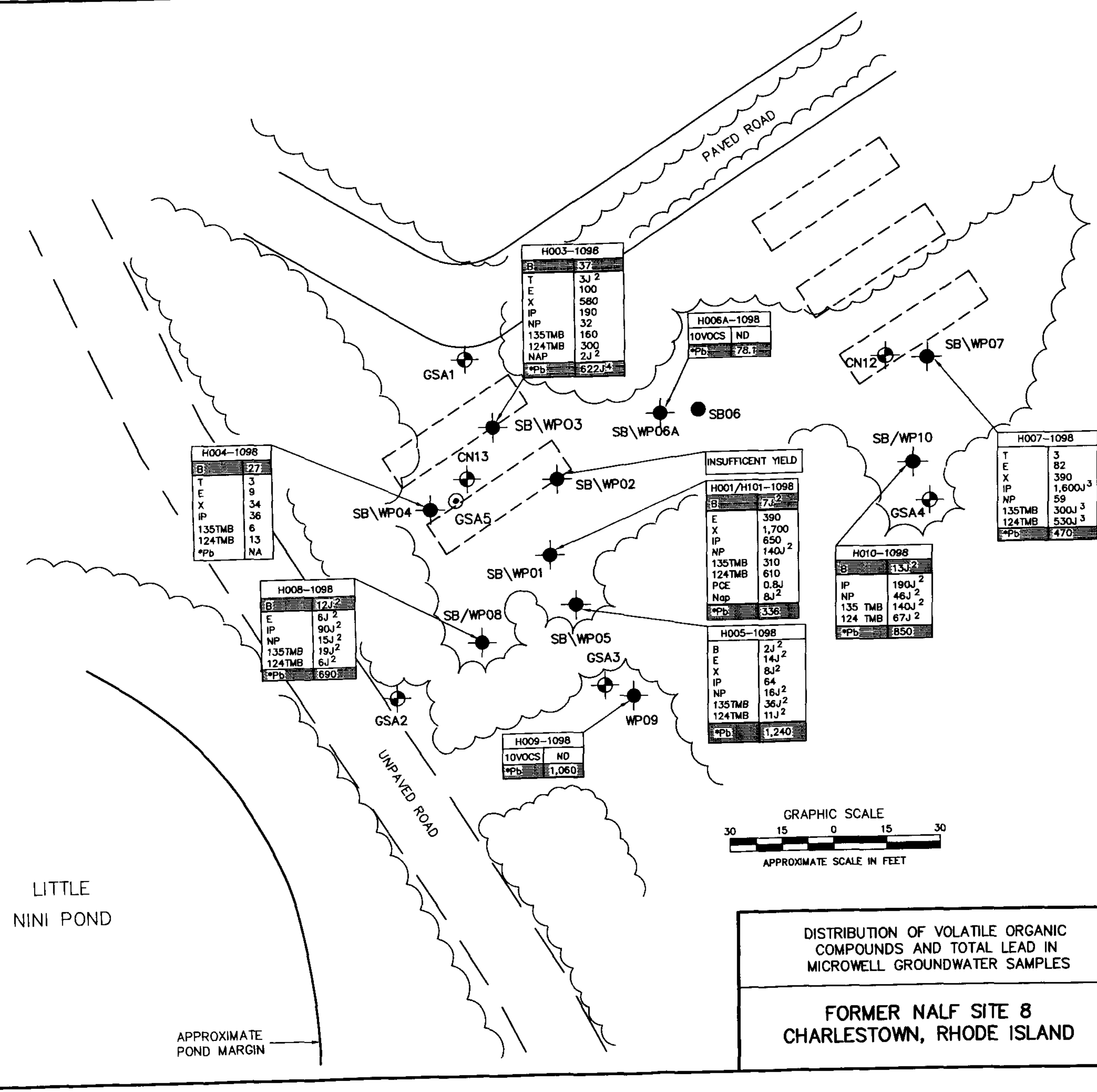
U=Compound not detected and sample practical quantitation level (PQL) shown.
UJ1=Compound qualified as nondetected due to two surrogate recoveries out of criteria. Estimated sample PQL is shown.
U2=Compound qualified as undetected due to lab blank contamination.
J=Compound detected below the sample PQL. Estimated concentration shown.
UJ2/J2=Estimated result due to one surrogate recovery above QC limits.
J3=Estimated result due to detection over the instrument calibration range.

The distribution of substances detected in microwell groundwater samples is shown in Figure 4-2. Analytical laboratory reports along with a validation summary memo and checklist are presented in Appendix C-3. Microwell construction logs are included in Appendix B.

Sheen was observed in microwell groundwater from locations WP01 to WP03, WP05, and WP08. In addition, a thin veneer of LNAPL was observed on groundwater at location WP08. The maximum microwell OVM/PID value of 428 parts per million (ppm) was detected at location WP08. At the time of the microwell survey, 1.25 ft of LNAPL was measured in well CN13. These data were used in conjunction with soil and monitor well observations to delineate an area of LNAPL and/or sheen in the vicinity of wells CN13 and GSA4 as shown on Figure 4-1. The presence of a measurable thickness of LNAPL in well CN13 exceeds the RIDEM Upper Concentration Limit (UCL) for a hazardous substance in groundwater.

Benzene and lead were detected at concentrations exceeding the RIDEM GA groundwater criteria. Other fuel-related VOCs were detected below the RIDEM GA criteria. The distribution of VOCs and lead detected in microwell groundwater samples is shown on Figure 4-2. Benzene was the only VOC detected above the RIDEM GA groundwater criteria, with a maximum concentration of 37 parts per billion (ppb) from microwell WP03.

Detected concentrations of lead in microwell groundwater exceeded RIDEM GA criteria at all locations analyzed. Some lead concentrations exceed the solubility limit of lead as tetraethyl lead (TEL) of 800 ppb (Verschueren, 1983). Water samples were not filtered, although samples were observed to be turbid. The microwells had very low yields due to the fine-grained character of site soils and the limited saturated screen thickness in tank pad areas due to refusals. The use of a peristaltic pump was precluded by the low well yields, and samples were collected using a bailer, that resulted in visually turbid samples containing suspended soil particles. Microwell WP04 yielded sufficient volume for VOC analysis only. Microwell SB02 remained dry after initial purging, and no samples were collected at that location. The observed lead results from microwell groundwater samples are significantly higher than the concentrations detected in the monitor well samples as described below.



LEGEND

B	BENZENE, ug/L
T	TOLUENE, ug/L
E	ETHYLBENZENE, ug/L
X	XYLENES, M+P, ug/L
IP	ISOPROPYLBENZENE, ug/L
NP	N-PROPYLBENZENE, ug/L
1,3,5TMB	1,3,5,TRIMETHYLBENZENE, ug/L
1,2,4TMB	1,2,4,TRIMETHYLBENZENE, ug/L
PCE	TETRACHLOROETHENE, ug/L
Nap	NAPHTHALENE, ug/kg
*Pb	TOTAL LEAD, ug/kg
ND	NOT DETECTED
10VOCs	INCLUDES ABOVE LISTED VOCs ONLY REFER TO ANALIYTICAL RESULT SUMMARY TABLE FOR COMPLETE LISTING AND RESULTS.

* SAMPLE FOR LEAD ANALYZED WERE OBSERVED TO BE TURBID AND ANALYZED UNFILTERED.

NOTE: REFER TO ANALYTICAL RESULT SUMMARY TABLE FOR EXPLANATION OF DATA QUALIFIERS.

GSA5	BEDROCK MONITOR WELL
GSA1	OVERBURDEN MONITOR WELL
SB06	HPSPU SOIL BORING
SB/WP01	HPSPU SOIL BORING AND MICROWELL
	APPROXIMATE FORMER UNDERGROUND TANK LOCATION

DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS AND TOTAL LEAD IN MICROWELL GROUNDWATER SAMPLES

FORMER NALF SITE 8
CHARLESTOWN, RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

WESTON
MANAGERS DESIGNERS/CONSULTANTS
MANCHESTER NEW HAMPSHIRE

DRAWN CDT
DATE MAR 99
FIGURE NO. 4-2

FILE NAME: G:\DES\DWG\ACOE\CHRLSTWN\FINAL\FIG4-2.DWG (PLOT 1=50)

Based on a comparison of the turbidity measured from the samples collected from the microwells and monitor wells, it is concluded that the microwell groundwater sample lead results are not representative of overburden groundwater concentrations. As discussed below, the monitor well sample results, having low turbidity, are considered representative of the overburden groundwater concentrations.

4.3 HPSPU SOIL SAMPLES

Observations from soil samples indicate that the site is underlain by a layer of well graded sand with gravel fill up to 15 ft thick locally within the footprint area of the former tanks. This fill layer is interpreted to be variable in thickness and locally extends down to the observed water table at the site. The dominant overburden lithology in undisturbed areas of the site is well graded sand with silt. No clay layers were observed. Refusal was encountered in borings at locations SB02, SB03, SB04 and GSA5 at approximately 15 ft bgs. Concrete fragments were observed in spoon samples and an 8-inch thick concrete core was recovered in the vicinity of the western UST locations indicating that one or more pads exist at depth underlying the former UST locations. Boring logs are presented in Appendix B.

Results of geotechnical analyses are presented in Appendix C-5. Grain size analysis of soil samples from the tank footprint area shows that the soils range from well graded sand with gravel (SW) to poorly graded silty sand with gravel (SM), with silt concentrations varying from approximately 5% to 30%.

Results from field screening of soil samples are summarized on Figure 4-1. A summary of the chemical analytical results from soil samples is presented in Table 4-2. The distribution of substances detected in soil samples are shown on Figure 4-3. Soil data analytical reports are included as Appendix C-2. Data from Katahdin Analytical Services, Inc. for soil samples collected October 12 and 13, 1998 were validated by WESTON. Chain of custody records were reviewed to verify holding times and sample conditions upon arrival. Analysis results sheets were reviewed and surrogate recoveries, matrix spike recoveries, laboratory blanks and field blanks, and field duplicate precision data were reviewed to ensure QC criteria were met and the Project WP followed. Discrepancies were noted on several pages of the report. The laboratory was

Table 4-2

Summary of Soil Analytical Results for VOCs, SVOCs, TPH-GRO, Total Lead, and SPLP-Lead for Samples Collected By WESTON on October 12 to 13, 1998 at the Former NALF - Site 8 Charlestown, Rhode Island

Parameter	Units	RIDEM Criteria[1]	S001-1098-12/13	S001-1098-14.3/15.2	S101-1098-14.3/15.2	S002-1098-8/9.6	S002-1098-12.7/13.6	S003-1098-8/9	S003-1098-12.5/14	S103-1098-12.5/14	S004-1098-8/10	S004-1098-12.3/13.3	S005-1098-15/16	S006-1098-13.5/14	S007-1098-4.5/5.5	TB-1
VOCs																
Chloromethane	ug/kg dry wt	NE	210U	300UJ[1]	690UJ[1]	370U	400J	250U	280U	NA	250U	190U	700U	180U	260U	250U
Bromomethane	ug/kg dry wt	800	210U	300UJ[1]	440J[1]	370U	550J	250U	280U	NA	250U	190U	610J	180U	260U	250U
Ethylbenzene	ug/kg dry wt	7,100	210U	300UJ[1]	520J[1]	370U	2,900	250U	280U	NA	250U	190U	700U	180U	260U	250U
Isopropylbenzene	ug/kg dry wt	12,000	210U	280J[1]	6,900J[1]	370U	2,600	250U	280U	NA	250U	190U	380J	180U	260U	250U
N-Propylbenzene	ug/kg dry wt	NE	210U	300UJ[1]	1,100J[1]	370U	580J	250U	280U	NA	250U	190U	700U	180U	260U	250U
1,3,5-Trimethylbenzene	ug/kg dry wt	NE	210U	190J[1]	16,000J[1]	370U	7,800	250U	280U	NA	250U	190U	700U	180U	260U	250U
1,2,4-Trimethylbenzene	ug/kg dry wt	NE	210U	360J[1]	8,600J[1]	370U	4,000	250U	280U	NA	250U	190U	700U	180U	260U	250U
Naphthalene	ug/kg dry wt	54,000	210U	300UJ[1]	690UJ[1]	370U	630J	250U	280U	NA	250U	190U	700U	180U	260U	250U
M+P-Xylene	ug/kg dry wt	110,000	210U	300U[1]	1,700J[1]	370U	9,300	250U	280U	NA	250U	190U	700U	180U	260U	250U
O-Xylene	ug/kg dry wt	110,000	210U	300U[1]	690U[1]	370U	750U	250U	280U	NA	250U	190U	700U	180U	260U	250U
TPH-GRO	mg/kg dry wt	500	2.5U	290J[2]	NA	2.8U	320	2.8U	270J[2]	400J[2]	2.8U	7.8	54	3U	29	2.5U
SVOCs																
Phenanthrene	ug/kg	40,000	NA	360U	NA	NA	400U	NA	360U	230J	NA	360U	NA	NA	NA	NA
Fluoranthene	ug/kg	20,000	NA	360U	NA	NA	400U	NA	360U	270J	NA	360U	NA	NA	NA	NA
Pyrene	ug/kg	13,000	NA	360U	NA	NA	400U	NA	360U	210J	NA	360U	NA	NA	NA	NA
Metals																
Total Lead	mg/kg dry wt	150	7.5	10.2	NA	14.4	12.2	11.8	15.7	17.7	5.1	5.3	6.1	6.3	8.5	NA
SPLP Lead	ug/L	40	3.7	NA	NA	2.8	NA	NA	12	10.3	NA	NA	NA	NA	NA	NA

[1] RIDEM Direct Exposure or Leachability Criteria.

Analysis methods are as follows: VOCs extracted/analyzed by EPA Method 5035/8260B; SVOCs extracted/analyzed by EPA Method 3540/8270C; TPH-GRO extracted/analyzed per EPA Method 5035/8015 Mod.; total lead extracted/analyzed by EPA Method 3050/6010; SPLP lead extracted/analyzed per EPA Method 1312.

NA = Not analyzed.

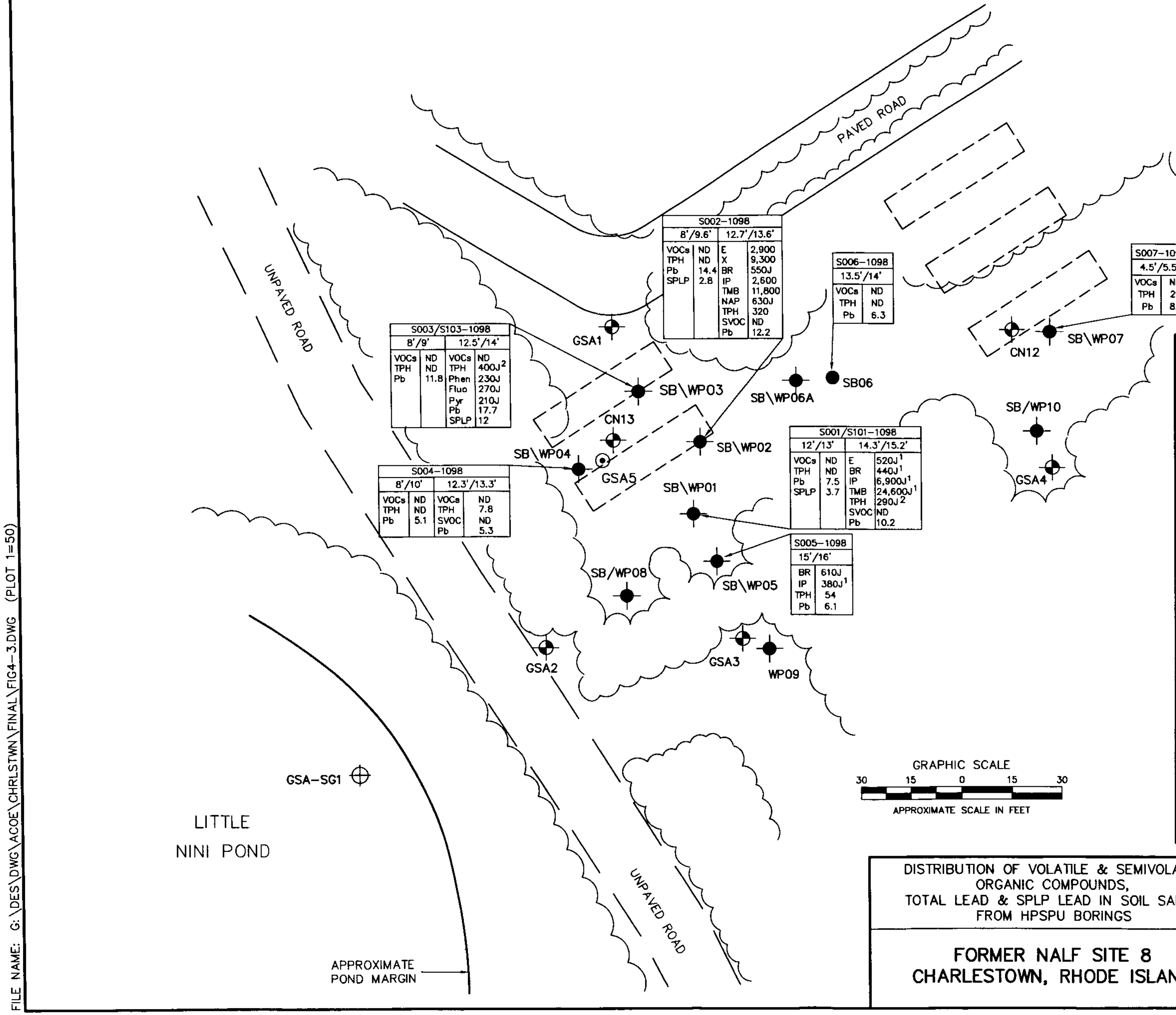
NE = Not established.

J=Estimated concentration due to detection below the sample practical quantitation limit (PQL).

J[1]/UJ[1]=Results or quantitation limit estimated due to field duplicate results out of criteria.

J[2]=Estimated positive result due to high surrogate recoveries.

U=Indicates compound was not detected and shows the sample PQL.



LEGEND

E	ETHYLBENZENE, ug/kg
X	XYLENES, M+P, ug/Kg
BR	BROMOMETHANE, ug/kg
IP	ISOPROPYLBENZENE, ug/kg
TMB	TOTAL TRIMETHYLBENZENES, (1,3,5-& 1,2,4-TMB)
Nap	NAPHTHALENE, ug/kg
TPH	TOTAL PETROLEUM HYDROCARBONS, mg/kg
Phen	PHENANTHRENE, ug/kg
Fluo	FLUORANTHENE, ug/kg
Pyr	PYRENE, ug/kg
Pb	TOTAL LEAD, mg/kg
SPLP	SPLP LEAD, ug/L
VOC	VOLATILE ORGANIC COMPOUNDS, ug/kg
SVOC	SEMIVOLATILE ORGANIC COMPOUNDS, ug/kg
ND	NOT DETECTED

NOTE: REFER TO ANALYTICAL RESULT SUMMARY TABLE FOR EXPLANATION OF DATA QUALIFIERS.

GSA-SG1	PIEZOMETER/STAFF GAUGE
SB06	HPSPU SOIL BORING
GSA1	OVERBURDEN MONITOR WELL
GSA5	BEDROCK MONITOR WELL
SB/WP01	HPSPU SOIL BORING AND MICROWELL
	APPROXIMATE FORMER UNDERGROUND TANK LOCATION

DISTRIBUTION OF VOLATILE & SEMIVOLATILE ORGANIC COMPOUNDS, TOTAL LEAD & SPLP LEAD IN SOIL SAMPLES FROM HPSPU BORINGS

FORMER NALF SITE 8
CHARLESTOWN, RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

WESTON
MANAGERS DESIGNERS/CONSULTANTS
MANCHESTER NEW HAMPSHIRE

DRAWN CDT
DATE MAR 99
FIGURE NO. 4-3

FILE NAME: G:\DES\DWG\ACOE\CHRLSTWN\FINAL\FIG4-3.DWG (PLOT 1=50)

contacted and resubmittals were sent with discrepancies corrected. Table 4-2 contains the corrected data. Results which have been qualified due to matrix spike or surrogate recoveries outside of QC limits, or poor duplicate results, have been flagged and foot-noted in Table 4-2. A summary memo of the results of data validation is included along with the data validation checklist in Appendix C-2.

Sheen was observed on soil samples from the smear zone, at or below the observed water table, at locations SB01 to SB05, and SB10. In addition, LNAPL was observed on a sample from location SB01. The maximum OVM/PID field screening result of 652 ppm (based on an isobutylene standard) was detected at location SB01. These data were used in conjunction with microwell data to delineate an area of LNAPL and/or sheen in the vicinity of wells CN13 and GSA4 as shown on Figure 4-1.

VOCs were not detected in soil samples collected from the vadose zone within the former tank footprint area. TPH-GRO was detected in vadose zone at only one location, SB07, with a concentration of 29 ppm from olive gray soil between 1.6 ft and 5.5 ft deep. Lead concentrations were detected in vadose zone soils below 15 ppm. SPLP-Lead concentrations were less than 4 ppb.

Smear zone soil samples contained concentrations of fuel-related VOCs and TPH-GRO, including ethylbenzene, xylene, trimethybenzenes, isopropylbenzene, bromomethane, and naphthalene. The maximum concentration of TPH-GRO detected in the smear zone was 400J[2] ppm at location SB03. Low concentrations of SVOCs were detected at location SB03 from smear zone soil, with maximum concentrations less than 300 ppb. Lead concentrations in smear zone soils were less than 18 ppm with a maximum SPLP-lead result of 12 ppb.

Concentrations of VOCs, TPH-GRO, SVOCs, lead and SPLP-lead detected in vadose zone and smear zone soil samples did not exceed RIDEM direct exposure and leachability criteria.

4.4 MONITOR WELL GROUNDWATER SAMPLES

On December 2 and 8, 1998, groundwater samples and QA/QC samples were collected by WESTON from five new monitor wells (GSA1 to GSA5) and two existing monitor wells (CN12 and CN13) at the site. Samples were analyzed by Katahdin Analytical Services, Inc. for VOCs, total lead, and the intrinsic bioremediation parameters ferrous iron, alkalinity, nitrate, and sulfate. Wells were purged and sampled using the USEPA low flow method. The parameters pH, temperature, conductivity, oxidation-reduction potential, dissolved oxygen, turbidity, and total organic vapor concentration (PID headspace) were measured in the field at the time of sample collection. A summary of the final field parameter readings are tabulated in Appendix F. Measured turbidity in samples from wells GSA-1, -2, -4, -5, CN-12, and CN–13 was low. The sample from well GSA-3 was observed to be slightly cloudy and had a moderately-high measured turbidity. A slight petroleum odor was noted in each of the samples, except GSA-5 in which no odor was detected. The detected odors correlate with field PID readings from the samples as shown in the Appendix F table. A summary of validated analytical results are presented in Table 4-3. Table 4-3 includes only detected substances. The distribution of detected organic compounds in groundwater samples from new and existing wells is shown on Figure 4-4. Analytical laboratory reports are included as Appendix C-1. These data were validated by WESTON according to procedures outlined in the Project Work Plan. Results of the validation are summarized in a memo included in Appendix C-1. Data qualifiers are defined on each data summary table.

Results of OVM/PID field screening analysis are summarized on Figure 4-1 along with soil and microwell groundwater screening results. During groundwater sampling, an LNAPL thickness of 0.47 ft was observed in well CN13. Sheen was observed on soil and groundwater from monitor well location GSA4. This location also had the highest observed OVM/PID monitor well groundwater reading of 81 ppm, exclusive of well CN13. Observations from well GSA4 and boring SB10 identified an area of sheen on the southeastern portion of the site. Monitor wells GSA1, GSA2, and GSA3 lie outside the area of observed sheen on the western portion of the site.

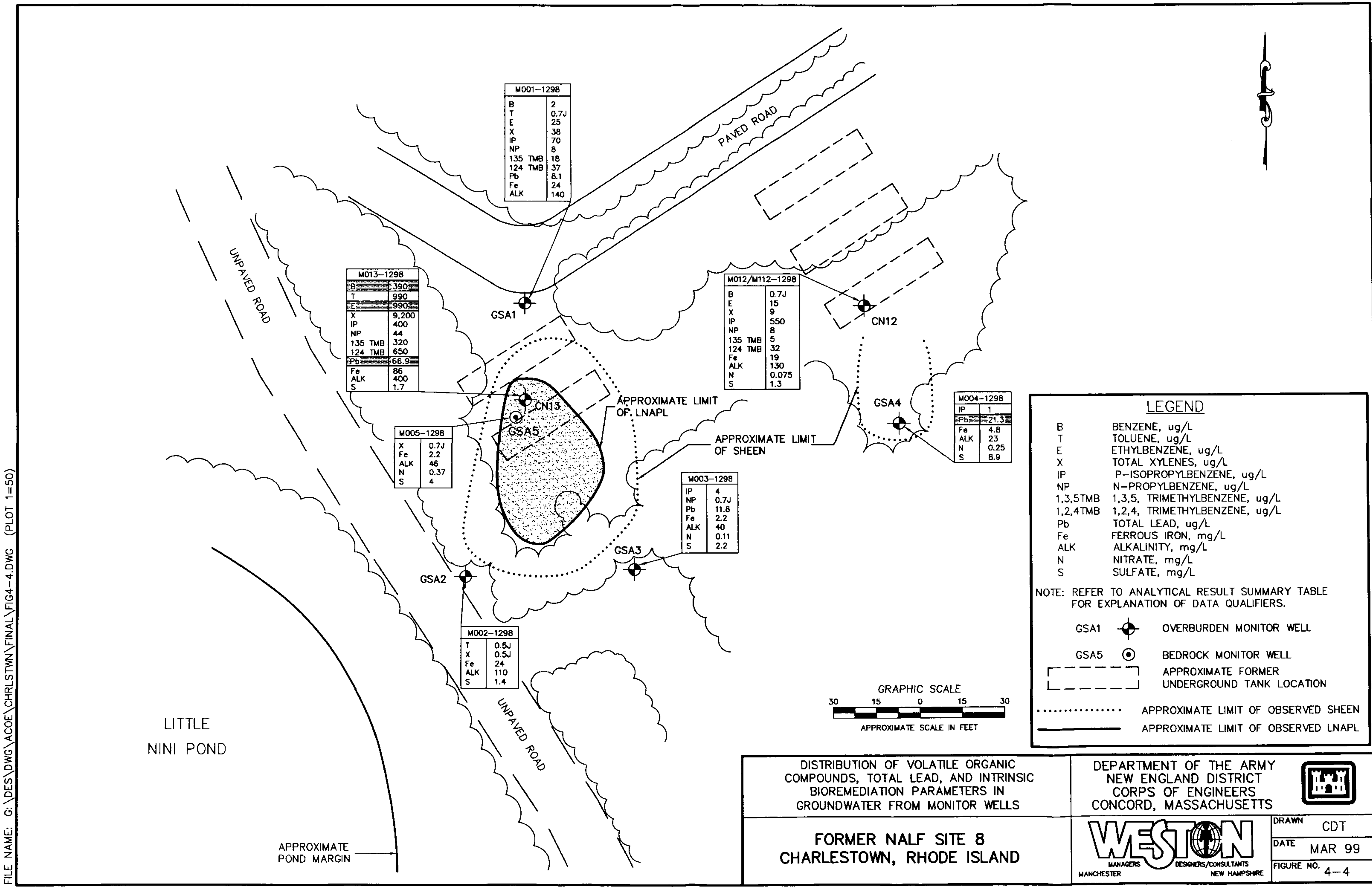
Table 4-3

Summary of Groundwater Analytical Results for VOCs, Lead, and Intrinsic Bioremediation Parameters for Samples Collected By WESTON on December 2 and 8, 1998 at the Former NALF-Site 8 Charlestown, Rhode Island

Parameter	Units	RIDEM GA Criteria*	M001-1298	M002-1298	M003-1298	M004-1298	M005-1298	M012-1298	M112-1298	M013-1298	M212-1298	TB-1	TB-2
VOCs													
Chloromethane	ug/L	NE	3	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U
Chloroform	ug/L	NE	1U	1U	1U	1U	1	1U	1U	1	1U	1U	1U
Benzene	ug/L	5	2	1U	1U	1U	1U	1U	0.7J	390	1U	1U	1U
Toluene	ug/L	1,000	0.7J	0.5J	1U	1U	1U	1U	1U	990	1U	1U	1U
Ethylbenzene	ug/L	700	25	1U	1U	1U	1U	14	15	990	1U	1U	1U
Isopropylbenzene	ug/L	NE	70	1U	4	1	1U	550	520	400	1U	1U	1U
N-Propylbenzene	ug/L	NE	8	1U	0.7J	1U	1U	7	8	44	1U	1U	1U
1,3,5-Trimethylbenzene	ug/L	NE	18	1U	1U	1U	1U	4	5	320	1U	1U	1U
Tert-Butylbenzene	ug/L	NE	1U	1U	1U	1U	1U	1	1	1	1U	1U	1U
Sec-Butylbenzene	ug/L	NE	0.5J	1U	1U	1U	1U	1	1	2U[1]	1U	1U	1U
P-Isopropyltoluene	ug/L	NE	1U	1U	1U	1U	1U	1U	1U	0.8J	1U	1U	1U
N-Butylbenzene	ug/L	NE	0.6J	1U	1U	1U	1U	1U	1U	3U[1]	1U	1U	1U
1,2,4-Trimethylbenzene	ug/L	NE	37	1U	1U	1U	1U	30	32	650	1U	1U	1U
2-Hexanone	ug/L	NE	4U	4U	4U	4U	4U	4U	4U	8	4U	4U	4U
Naphthalene	*ug/L*	*20*	*1*	*1U*	*1U*	*1U*	*1U*	*1*	*1*	*7*	*1U*	*1U*	*1U*
Acetone	ug/L	NE	5	6	4J	3J	5U	3J	4J	8	5U	5U	3J
M+P-Xylene	ug/L	10,000	38	0.5J	1U	1U	0.7J	9	9	6900	1U	1U	1U
O-Xylene	*ug/L*	*10,000*	*1U*	*1U*	*1U*	*1U*	*1U*	*1U*	*1U*	*2300*	*1U*	*1U*	*1U*
Inorganics													
Total Lead	ug/L	15	8.1	2.2U[1]	11.8	21.3	2.8U[1]	4.3U[1]	4.6U[1]	66.9	1.31U[2]	NA	NA
Ferrous Iron	mg/L	NE	24	24	2.2	4.8	2.2	19	18	86	NA	NA	NA
Alkalinity	mg/L	NE	140	110	40	23	46	130	130	400	NA	NA	NA
Nitrate	*mg/L*	*NE*	*0.05U*	*0.05U*	*0.11*	*0.25*	*0.37*	*0.062*	*0.075*	*0.05U*	*NA*	*NA*	*NA*
Sulfate	mg/L	NE	1U	1.4	2.2	8.9	4	1.3	1U	1.7	NA	NA	NA

Samples for VOCs extracted by EPA Method 5030B and analyzed per EPA Method 8260B.
Samples for total lead extracted by EPA Method 3010B and analyzed per EPA Method 6010B.
Ferrous iron, alkalinity, nitrate and sulfate were analyzed by methods SM3500D, E310.1, 353.2 and 375.4, respectively.
U = Parameter not detected above the sample practical quantitation limit (PQL). The sample PQL is shown.
J = The value shown is estimated due to detection below the sample PQL.
U1=Positive result qualified as non-detect due to laboratory preparation blank contamination.
U2=Positive result qualified an non-detect due to laboratory method blank contamination.

FILE NAME: G:\DES\DWG\ACOE\CHRLSTWN\FINAL\FIG4-4.DWG (PLOT 1=50)



Results from monitor well groundwater samples show exceedances of RIDEM GA groundwater criteria for the VOCs benzene and ethylbenzene only in well CN13. Low concentrations of fuel-related VOCs were detected in samples from each of the wells tested, excluding well CN13. A trace of xylene was the only VOC detected in bedrock well GSA5, located within the area of the LNAPL plume. Lead was detected in samples from wells GSA1, GSA3 and GSA4. The levels of detected lead in wells CN13 and GSA4 exceeded the RIDEM GA groundwater criteria with concentrations of 66.9 ppb and 21.3 ppb, respectively. The samples were analyzed unfiltered, however, the turbidity of the samples collected from wells CN13 and GSA4 were field analyzed and found to be below 5 nephelometric turbidity units (NTUs). As a result, lead these concentrations are considered representative of the overburden groundwater, and do not appear affected by sample turbidity.

Results of laboratory analyzed intrinsic bioremediation parameters are summarized on Figure 4-4. Data from field-analyzed parameters are listed in Appendix F. The highest concentrations of ferrous iron and alkalinity were detected in source area well CN13. The maximum detected nitrate concentration of 0.37 milligram per liter (mg/L) is below the USEPA maximum contaminant level (MCL) of 1 mg/L. The maximum concentration of sulfate of 8.9 mg/L was detected in well GSA4, below the USEPA secondary MCL (SMCL) of 250 mg/L. Parameter trends are discussed in more detail in Section 5.

4.5 RESULTS OF LNAPL AND WATER LEVEL MONITORING

Water and LNAPL elevation data collected during this investigation includes groundwater and product levels from ten temporary microwells, seven permanent monitor wells, and one piezometer/staff gauge. In addition, historical water/product level data from existing wells were examined. Monitoring for tidal influence on groundwater flow was not conducted as part of this investigation.

Groundwater and LNAPL levels were measured in ten microwells and two existing monitor wells at the site during the HPSPU survey on October 12 and 13, 1998. Water and product levels were recorded as elevations referenced to mean sea level based on surveyed ground surface elevations at each microwell location, and as such, the precision of the relative microwell groundwater elevations is considered to be +/-0.1 ft rather than +/-0.01 ft. These data are summarized in Table 4-4.

The presence of product in microwells was determined using a transparent bailer. An electronic oil/water interface probe was used in monitor wells, in addition to bailer examination. These data were used to produce a potentiometric surface contour map of overburden groundwater presented as Figure 4-5. This figure illustrates that the interpreted overburden groundwater flow at the site at the time of measurement is directed toward the south/southeast. No water level information from Little Nini Pond was available at the time of this survey. LNAPL was observed at locations CN13 and WP08 during the HPSPU survey. LNAPL was observed in well CN13 with a thickness of 1.25 ft. A veneer of LNAPL less than 1/8 inch thick was observed in microwell WP08.

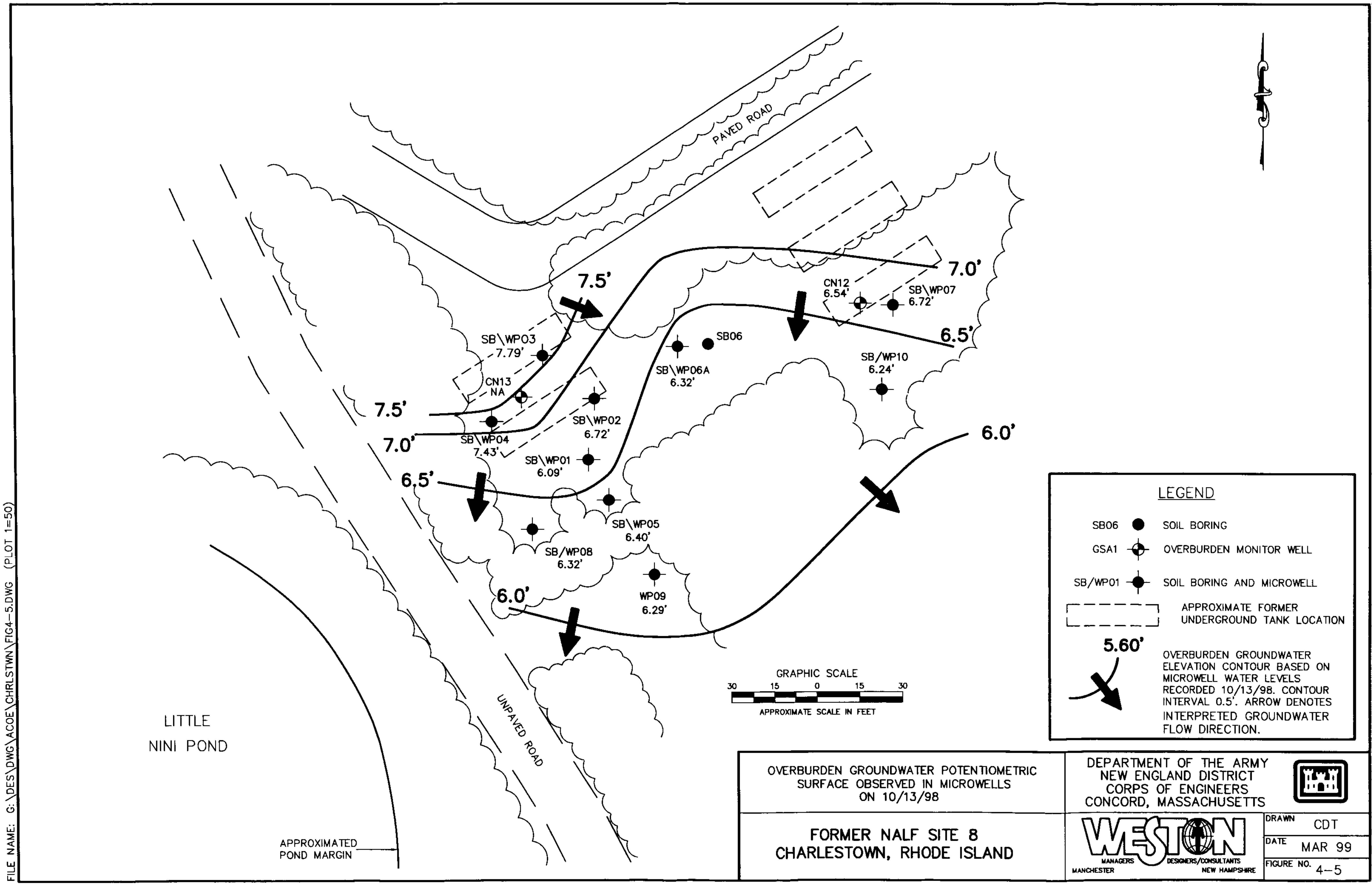
On December 2, 8 and 9, 1998, groundwater (3 rounds) and LNAPL (2 rounds) levels were recorded in five new and two existing monitor wells, and one piezometer at the site. These data are summarized in Table 4-5. Measurements from the December 2nd round were used to produce a potentiometric surface contour map of overburden groundwater presented as Figure 4-6. This figure illustrates that the interpreted overburden groundwater flow at the site at the time of measurement is directed toward the southwest at a very low horizontal hydraulic gradient. Water levels from the piezometer in Little Nini Pond indicate that groundwater flow is directed radially away from the pond in that vicinity. Water levels recorded on the northwest margin of the site suggest that an area of stagnant overburden groundwater may exist in this area. The groundwater flow conceptual model is discussed further in Section 5.

Table 4-4

Water Level Elevation Data From Microwells at the Former NALF-Site 8 Charlestown, Rhode Island

Well ID	GS Elev	Stick Up	Date: 10/13/98		
			TIC Elev	DTW (TIC)	Water Elevation
WP01	20.53	2.1	22.63	16.54	6.09
WP02	20.26	1.24	21.5	14.78	6.72
WP03	20.78	0.88	21.66	13.87	7.79
WP04	20.94	0.69	21.63	14.20	7.43
WP05	19.89	1.31	21.2	14.80	6.40
WP06A	20.98	0.32	21.3	14.98	6.32
WP07	20.48	3.36	23.84	17.12	6.72
WP08	19.96	1.35	21.31	14.99	6.32
WP09	19.42	0.47	19.89	13.60	6.29
WP10	20.1	3	23.1	16.86	6.24
CN12	20.93	2	22.93	16.39	6.54

GS Elev = Ground Surface Elevation.
TIC Elev = Top of Inner Casing Elevation.
DTW = Depth to water from top of inner casing.
Water Elevation = Groundwater elevation above mean sea level.



FILE NAME: G:\DES\DWG\ACOE\CHRLSTWN\FIG4-5.DWG (PLOT 1=50)

OVERBURDEN GROUNDWATER POTENTIOMETRIC SURFACE OBSERVED IN MICROWELLS ON 10/13/98

FORMER NALF SITE 8
CHARLESTOWN, RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

WESTON
MANAGERS DESIGNERS/CONSULTANTS
MANCHESTER NEW HAMPSHIRE

DRAWN	CDT
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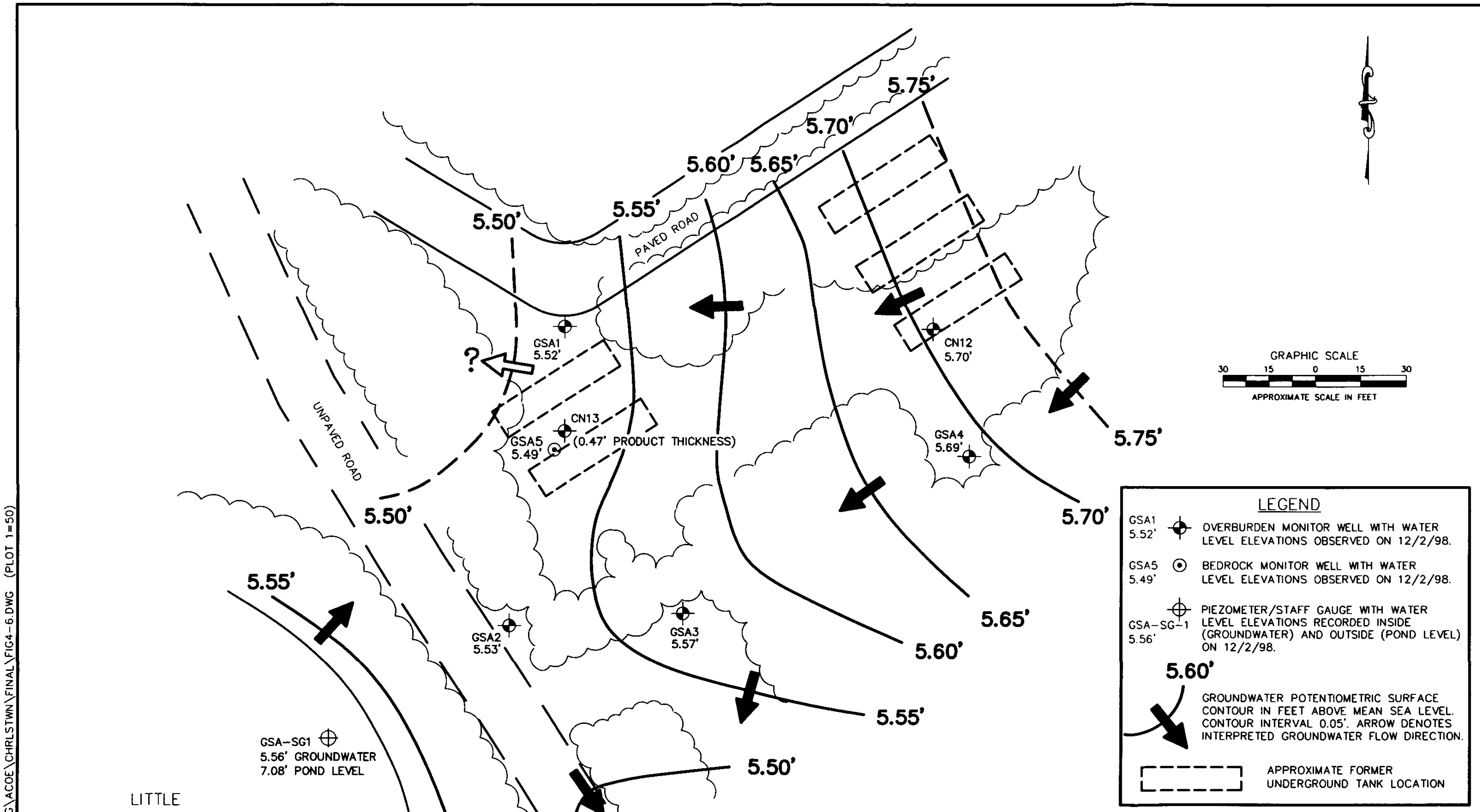
FIGURE NO.	4-5

Table 4-5

Water Level Elevations From Monitor Wells Recorded on December 2, 8, and 9, 1998 at the Former NALF-Site 8, Charlestown, Rhode Island

Well ID	GS Elev	Date:	12/2/98			12/8/98			12/9/98		
		TIC Elev	Time	DTW	Water Elev	Time	DTW	Water Elev	Time	DTW	Water Elev
GSA-1	21.82	24.24	9:26	18.72	5.52	7:37	18.81	5.43	13:00	18.83	5.41
GSA-2	21.26	21.04	9:24	15.51	5.53	7:51	15.61	5.43	13:25	15.62	5.42
GSA-3	19.71	22.11	9:31	16.54	5.57	7:42	16.62	5.49	13:21	16.64	5.47
GSA-4	20.24	22.92	9:29	17.23	5.69	7:40	17.32	5.60	13:17	17.34	5.58
GSA-5	20.97	23.68	9:32	18.19	5.49	7:43	18.29	5.39	13:15	18.3	5.38
CN-12	20.93	22.93	9:28	17.23	5.70	7:39	17.33	5.60	13:16	17.35	5.58
GSA-SG-1 (outside - pond level)	5.92	8.72	9:17	1.64	7.08	7:55	1.81	6.91	13:48	1.81	6.91
GSA-SG-1 (inside - groundwater level)	5.92	8.72	9:15	3.16	5.56	7:53	3.27	5.45	13:48	3.29	5.43
CN-13	21.18	22.74	9:39	17.67* (0.47' PT) 18.14	4.60	7:45	17.22* (0.34' PT) 17.56	5.18	NA	NA NA	

GS Elev = Ground Surface Elevation.
TIC Elev = Top of Inner Casing Elevation.
DTW = Depth to water from top of inner casing.
Water Elev = Groundwater elevation.
* = Depth to product level from top of inner casing. Product was only detected in monitoring well CN-13.
NA = Not available.
PT = Product Thickness



OVERBURDEN GROUNDWATER POTENTIOMETRIC SURFACE OBSERVED IN MONITOR WELLS ON 12/2/98

FORMER NALF SITE 8
CHARLESTOWN, RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

WESTON
MANAGERS DESIGNERS/CONSULTANTS
MANCHESTER NEW HAMPSHIRE

DRAWN	BEG
DATE	JAN 2001
FIGURE NO.	4-6

FILE NAME: G:\DES\DWG\ACOE\CHRLSTWN\FINAL\FIG4-6.DWG (PLOT 1=50)

Historical data from the well CN12 indicate water table fluctuations up to approximately 2.74 ft at the site. Reported yearly fluctuations of nearly 4 ft and maximum historical fluctuations of almost 9 ft have been reported based on US Geological Survey (USGS) data at the former NALF.

4.6 RESULTS OF PERMEABILITY TESTING

Fifteen rising and falling head slug tests were performed on the five new and one existing (CN12) monitor wells at the site. Estimates of the overburden hydraulic conductivity at the site were calculated from the data of each test by the Bouwer and Rice method (Bouwer and Rice, 1976). These results are summarized in Table 4-6. Time versus water level graphs from each test are included in Appendix D. Hydraulic conductivity values determined from rising head tests in on-site monitor wells range from 1.4E-04 cm/s to 1.6E-02 cm/s in overburden. These values are consistent with known ranges of hydraulic conductivity values for fine sand and silty sand soils. The hydraulic conductivity of the bedrock was estimated from well GSA5 at 1.23E-02.

Laboratory-determined conductivity values derived from vadose zone soil samples collected from the western portion of the source area range from 2.8E-04 cm/s to 2.8E-03 cm/s. These values are consistent with slug test results from monitor wells. Comparison of these values to the value from well CN12 suggests variability in source area fill, such that some areas of the tank footprint contain soils similar to the natural soils nearby.

4.7 INVESTIGATION DERIVED WASTE

One 55-gallon drum of investigation-derived waste (IDW) liquid was generated during the investigation and stored on a wooden pallet on-site. The drum contained a mixture of LNAPL and groundwater purged from monitor well CN13. Analytical results generated during this investigation were used to characterize the IDW for disposal. This containerized IDW was manifested and transported off-site on February 22, 1999 by Franklin Environmental Services of Wrentham, Massachusetts for disposal by Northland Environmental of Providence, Rhode (manifest No. MAK062772).

Table 4-6

Summary of Slug Test Hydraulic Conductivity Results from On-Site Monitor Wells at the Former NALF-Site 8, Charlestown, Rhode Island

Monitoring Well Location	Total Depth (ft - TIC)	Screened Interval (ft)	Well Diameter (in)	Test Type and Number	Hydraulic Conductivity	
					ft/day	cm/second
GSA-1	21.6	11.6 - 21.6	2	Falling Head 1	1.2	4.23E-04
				Rising Head 1	1.4	4.94E-04
GSA-2	24.0	9.0 - 24.0	2	Falling Head 1	0.4	1.41E-04
				Rising Head 1	0.4	1.41E-04
GSA-3	26.5	11.5 - 26.5	2	Falling Head 1	0.7	2.47E-04
				Rising Head 1	0.7	2.47E-04
				Rising Head 2	0.6	2.12E-04
GSA-4	27.1	12.1 - 27.1	2	Falling Head 1	25.3	8.92E-03
				Rising Head 1	25.0	8.82E-03
GSA-5	53.0	37.0 - 53.0 (open hole)	3	Falling Head 1	27.7	9.77E-03
				Rising Head 1	29.4	1.04E-02
				Rising Head 2	35.0	1.23E-02
CN-12	25.0	15.0 - 25.0	2	Falling Head 1	44.0	1.55E-02
				Rising Head 1	45.0	1.59E-02
				Rising Head 2	45.3	1.60E-02

* Note: All hydraulic conductivity values calculated using Bouwer-Rice Method.

WESTON managed the transport and disposal of the IDW as agent for the Department of Defense (DOD) following CENAE guidelines. Manifest documents, waste profiles and supporting documentation are included in Appendix G. The Certificate of Disposal has not been received from Northland Environmental Inc.

SECTION 5

DISCUSSION OF RESULTS

5. DISCUSSION OF RESULTS

This Phase II Engineering Evaluation of Contamination Report is a presentation of data collected to date, including background information provided by CENAE, and observations made during the WESTON HPSPU soil boring/microwell survey, monitor well installations, groundwater sampling, and hydrogeologic testing. These data are integrated into an interpretation of the contaminant characterization and distribution at the site, and conceptual model of site hydrogeology in the following section. This information forms the basis of the preliminary evaluation of remedial alternatives at the site presented in Section 6.

5.1 ESTIMATED EXTENT OF LNAPL

The estimated extent of LNAPL has been documented based on the following information:

- Observations from 10 microwells, and 7 monitor wells across the site as listed in Section 4 and presented graphically on Figures 4-1 and 4-4.
- Observations from 11 soil borings.
- Results of off-site analysis of soil and groundwater samples collected from microwell and monitor well locations.
- Data from previous investigations performed by IT (1993).

One area of LNAPL was documented during the HPSPU boring/microwell survey encompassing an estimated maximum area of 4,400 ft^2 of the western portion of the site as outlined on Figures 4-1 and 4-4. The area of LNAPL extends southward approximately 30 ft from the footprint of two of the former gasoline USTs. This area is slightly larger than that described in the previous IT hydropunch study. LNAPL was observed on a water table soil sample from location SB01. A thin veneer of LNAPL was observed in microwell WP08. The initial measured thickness of LNAPL in well CN13 was 1.25 ft recorded on October 13, 1998, prior to bailing. Sheen only was observed on soil and groundwater from locations SB/WP02, SB/WP03, and SB/WP05. Sheen only was observed on soil samples from locations SB10, GSA4 and GSA5. These observations are consistent with PID field screening measurements summarized on Figure 4-1. The approximate limit of observed sheen is shown on Figures 4-1 and 4-4. The area of sheen surrounding the LNAPL plume encompasses approximately 6,500 ft^2. An area of sheen was observed in the vicinity of microwell WP10 and well GSA4 that likely extends from the former tanks in the vicinity of well CN12. A measurable thickness of LNAPL was observed only in well CN13.

5.2 CHEMICAL CONSTITUENTS IN SOIL

Analytical results from soil samples collected from seven locations in the vicinity of the former tank footprint area include the detection of VOCs, SVOCs, TPH-GRO, SPLP-lead and lead. Results are summarized in Table 4-2 and their distribution shown on Figure 4-3. None of the concentrations of organic compounds or lead detected in soil exceeded the RIDEM Method 1 residential direct exposure or GA leachability criteria for soil in the vadose zone or smear zone at the site. As a result, soil remediation is not warranted.

The highest concentrations of detected compounds were from samples collected at the vadose zone/water table interface. Samples from boring locations SB01, SB02 and SB03 had the highest concentrations of substances detected. These locations are within or in close proximity to the LNAPL plume intercepted by well CN13. The VOCs ethylbenzene, xylene, bromomethane, isopropylbenzene, trimethylbenzenes, and naphthalene had the highest concentrations. Benzene was not detected in soil samples. Low levels of the SVOCs phenanthrene, fluoranthene, and pyrene were detected only in boring SB03. TPH-GRO concentrations ranging from 290 to 400 milligrams per kilogram (mg/kg) were detected in the vicinity of the LNAPL plume at the depth of the water table (locations SB01 to SB03). Outside this area, TPH levels were less than 55 mg/kg. TPH was detected in one petroleum-stained, vadose-zone soil sample from location SB07 at a concentration of 29 mg/kg. Low levels of lead were detected in soil samples, although concentrations detected in shallow soils were similar to those detected at the depth of the water table. Concentrations of SPLP-lead were detected well below the RIDEM GA leachability criteria.

5.3 CHEMICAL CONSTITUENTS IN LNAPL AND GROUNDWATER

One LNAPL sample was collected for Simulated Distillation analysis for use in evaluating remedial options. The analytical result is included in Appendix C and discussed further in Section 6. The result reveals the relationship between individual components of the petroleum hydrocarbon, boiling point and percent of sample weight. Based on this result, approximately 64% of the LNAPL falls within the volatile range including carbon chain lengths of up to 12. Previous reports indicated that the LNAPL was unweathered leaded gasoline. Results from VOC, SVOC and lead analyses of soil and groundwater are consistent with this characterization.

The results of the analyses of microwell groundwater samples show that the primary contaminants in groundwater are GRO compounds consisting of benzene, ethylbenzene, xylenes, isopropylbenzene, N-propylbenzene, trimethylbenzenes, and naphthalene. A trace concentration of tetrachloroethene was detected in one sample. Concentrations of benzene exceeded the RIDEM GA groundwater criteria in samples from five locations denoted by shading on Figure 4-2, with a maximum concentration of 37 micrograms per liter (µg/L) at location WP03. Concentrations of lead were detected in microwell water samples above the RIDEM GA criteria. Importantly, microwell groundwater samples were observed to be turbid at the time of collection, resulting from the very low well yields. Many of the observed lead concentrations exceeded lead solubility levels. Lead results from microwell samples are not considered representative of dissolved groundwater concentrations because the samples were analyzed unfiltered. This is supported by a comparison of lead concentrations detected in soil samples with results of the SPLP analysis of the same samples as shown in Figure 4-3, and results from monitor well groundwater samples shown on Figure 4-4 and discussed below.

Analytical results from monitor well groundwater samples showed the same VOCs as in the microwell groundwater samples, however, at significantly lower concentrations. This is likely due to the lack of suspended solids in monitor well samples, and the more distant locations from the source area. Benzene and ethylbenzene exceeded the RIDEM GA groundwater criteria only in well CN13, where LNAPL is present, with concentrations of 390 µg/L and 990 µg/L, respectively. Benzene was detected at low concentrations in wells GSA1 and CN12. No VOC exceedances were detected in wells outside the LNAPL plume. A trace level of xylene was detected in bedrock well GSA5, located within the area of the LNAPL plume.

Lead was detected in groundwater samples from four of the on-site monitor wells; CN13, GSA1, GSA3, and GSA4 (Figure 4-4). Lead was not detected in overburden wells CN12 and GSA2 and bedrock well GSA5. The lead concentrations detected in wells CN13 and GSA4 exceeded RIDEM GA criteria with values of 66.9 μg/L and 21.3 μg/L, respectively. Turbidity values of these two samples were field measured below 5 NTUs. Groundwater samples were analyzed unfiltered.

Groundwater sample results from analysis of intrinsic bioremediation parameters ferrous iron, alkalinity, sulfate, and nitrate are included on Figure 4-4. Ferrous iron concentrations ranged from 86 mg/L within the source area to 2.2 mg/L downgradient of the source area and within the bedrock. Alkalinity values ranged from 400 mg/L in the source area to 23 mg/L downgradient of the source area. Sulfate was detected at low concentrations with values ranging from 8.9 mg/L to 1.4 mg/L. Sulfate was not detected in well GSA1. Low concentrations of nitrate were detected in four wells, with values ranging from 0.37 mg/L to 0.075 mg/L. Nitrate was not detected in wells CN13, GSA1, and GSA2.

According to Buschek and O'Reilly (1995), changes in the levels of ORP, DO, alkalinity, sulfate, nitrate, and ferrous iron can be used to indicate whether aerobic or anaerobic biodegradation of a hydrocarbon plume is occurring. A comparison of existing data from a transect of wells across the source area GSA1-CN13-GSA3 as shown on Figure 4-4 and in Table 4-3, revealed the following qualitative trends in the intrinsic bioremediation parameters across the source area. ORP readings on groundwater samples decreased in the source area, while alkalinity and ferrous iron increased in the source area. These trends suggest that active anaerobic biodegradation of the plume is occurring. The slight increase in sulfate concentration from upgradient to downgradient locations may also be correlated with anaerobic biodegradation of the plume. There is a lack of correlation across the plume for levels of dissolved oxygen and nitrate, which are indicative of aerobic processes. Existing data is insufficient to determine rates of biodegradation of the existing plume. Current data suggests that anaerobic biodegradation is the dominant active intrinsic bioremediation process at the site.

5.4 HYDROGEOLOGIC ANALYSIS

The overburden groundwater contour map drawn from data collected during the microwell survey in October 1998 indicates that overburden groundwater flow was directed toward the south-southeast across the site with an estimated hydraulic gradient of about 0.02 at the time of the survey (Figure 4-5). This pattern is consistent with the observed contaminant plume distribution and observations provided in the Phase I report by IT.

Groundwater elevation data from new and existing monitor wells and a staff gauge/piezometer monitored in December 1998 data also indicate a very low hydraulic gradient at the site, resulting in a complex overburden groundwater flow pattern as shown on the potentiometric surface map on Figure 4-6. The pattern shown on Figure 4-6 illustrates that overburden groundwater was flowing from northeast to southwest with a hydraulic gradient of 0.001 across the site at the time of the survey. This suggests an area of groundwater recharge east-northeast of the site. In addition, water levels along the northwest margin of the site suggest that overburden groundwater may be stagnant in this area.

Measurements collected in December 1998 from the piezometer at the eastern margin of Little Nini Pond indicate a strong vertical gradient at location GSA-SG1 of about 0.4, between the surface water in the pond and the underlying groundwater. This gradient contrasts sharply with the horizontal gradient less than 0.001 indicated by the groundwater elevation recorded in nearby well GSA2. As a result, groundwater is interpreted to slowly flow radially away from the pond as shown in Figure 4-6, such that an area of groundwater stagnation may exist in the area northwest of wells CN13 and GSA1, and that groundwater flow south of well GSA2 is directed to the southeast. Importantly, this pattern is sensitive to the very small groundwater elevation differences recorded between wells GSA1, GSA2, GSA3 and GSA-SG1, and the low horizontal flow gradient observed. The limited lateral extent of the contaminant plume at the site is consistent with the low hydraulic gradients observed.

A comparison of monitor well groundwater elevation data with microwell data collected two months earlier indicates water table fluctuation of approximately 0.75 ft at the site during this period. The variations in interpreted overburden groundwater flow patterns between October and

December 1998 as described above (Figures 4-5 and 4-6), suggest that the hydraulic gradient and groundwater flow patterns at the site are sensitive to seasonal rainfall variations.

The variations in hydraulic conductivity values between well locations are consistent with observed soil characteristics at each location. The highest hydraulic conductivity values were observed in overburden well CN12 screened in loosely consolidated source area fill, and the open-hole bedrock well GSA5. Wells GSA1, GSA2, and GSA3 are screened in undisturbed silty sand, while well GSA4 is screened in undisturbed sand with gravel. Importantly, the lower hydraulic conductivity values observed in the area outside the tank footprint area have likely contributed to the limited migration of the contaminant plume beyond the source area. In addition, the higher hydraulic conductivity value in the source area favors the implementation of contaminant remediation.

Seepage velocities were estimated using the hydraulic conductivity values presented in Table 4-6 and a horizontal gradient of 0.001. An effective porosity of 30% was assumed for the purpose of estimating the seepage velocities for sandy soils. The resulting seepage velocities calculated using these values range from 0.5 - 1.6 ft/yr in silty fine sand soils (wells GSA1, GSA2, and GSA3) and from 29 - 53 ft/yr in sand and gravel soil/fill (wells GSA4 and CN12). These values are consistent with the limited lateral extent of the contaminant plume observed at the site.

Analysis of bedrock core from th~~e shallow bedrock at location GSA5 indicates that the bedrock~~ underlying the site is coarse-grained, pink, biotite-quartz-feldspar granite with abundant planar, smooth, slightly iron-stained fractures. Rock Quality Determination (RQD) value was zero for the 16 ft core interval. A thin fault gouge zone composed of altered granite was also encountered in the core. The hydraulic conductivity value measured in well GSA5 is consistent with the presence of open fractures observed in the bedrock core. The small difference in water level elevations measured in well GSA5 and nearby overburden well GSA1 indicates a very weak downward vertical gradient of approximately 0.001 between the bedrock and overburden in the source area. A weak downward flow gradient is consistent with the lack of contamination observed in bedrock well GSA5.

SECTION 6

ANALYSIS OF REMEDIATION ALTERNATIVES

6. ANALYSIS OF REMEDIATION ALTERNATIVES

6.1 REMEDIAL OBJECTIVES

The evaluation of remedial alternatives is conducted for the purpose of recommending appropriate remedial action to reduce contaminant concentrations below remedial objectives. The remedial objectives currently considered for this site are based on the RIDEM, Division of Site Remediation, *Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases* (DEM-DSR-01-93), as amended August 1996. Chemical concentrations measured in the soil and groundwater samples collected at the site were compared to Method 1 Direct Exposure Criteria for Residential sites, GA Leachability Criteria for soil, GA Groundwater Objectives, and Upper Concentration Limits. Remedial alternatives considered are based on the RIDEM remedial objectives listed above in the absence of a risk assessment for the Site.

Soil data from this study do not indicate concentrations of organic compounds or lead above RIDEM direct exposure criteria or leachability criteria in the vadose zone or smear zone at the site. As a result, soil remediation is not warranted, and soil remedial alternatives were not reviewed.

Based on existing data, the following areas have been identified that may require remediation at the site:

- The LNAPL plume, located south of the former location of the gasoline USTs on the western portion of the site, as shown in Figure 4-4. Benzene and lead concentrations exceed RIDEM GA groundwater objectives. The presence of LNAPL exceeds the UCL criteria for soil and groundwater.

- Lead has been detected in groundwater near monitor well GSA4 with concentrations exceeding RIDEM GA Groundwater objectives.

- Sheen was observed on groundwater from the piezometer in Little Nini Pond. Although the observed sheen may be naturally-occurring organic material, or from a source unrelated to the UST area, the source of the sheen has not been confirmed. The presence of sheen, if petroleum related, may indicate the presence of compounds exceeding RIDEM GA groundwater criteria.

It should be noted that no risk assessment has been conducted for the site. Although some lead concentrations in groundwater exceed GA groundwater objectives, it is unknown if remediation for lead will be needed based on actual risk.

6.2 DATA GAPS

WESTON has identified the following data gaps with recommendations for necessary additional investigation prior to final selection of a remedial alternative for this site:

- The potential risk related to lead in groundwater needs further evaluation. The resampling of monitor wells CN13, GSA3, CN12 and GSA4 for total and dissolved lead analysis is recommended in order to confirm the dissolved lead concentrations in the source areas.

- The source of sheen on groundwater from piezometer GSA-SG1 in Little Nini Pond needs to be evaluated. It is recommended that one groundwater sample be collected for VOCs and dissolved lead from the piezometer to characterize the sheen.

- In order to determine the most appropriate remedial method for groundwater at the site, a risk assessment should be conducted based on existing data to determine whether a significant risk to human health and the environment from lead in groundwater exists at the site.

If contamination related to the observed releases at Site 8 is found in groundwater from the piezometer in Little Nini Pond, sediment and surface water at the eastern margin of the pond will require additional evaluation. In addition, more focussed sampling (Acid Volatile Sulfides/Simultaneously Extracted Metals) of the sediment may be needed to evaluate potential risk to environmental receptors.

6.3 IDENTIFICATION AND INITIAL SCREENING OF REMEDIAL ALTERNATIVES

The following remedial technologies and the No Action or Limited Action alternative for LNAPL and/or lead remediation were screened based on review of sites with similar contaminants, and consultation of the USEPA Risk Reduction Engineering Laboratory (RREL), Vendor Information System For Innovative Treatment Technologies (VISITT), and Treatability Databases (TDB):

- No Action or Limited Action
- Product Recovery Wells and Pumps
- Soil Vapor Extraction (SVE) / Bioventing
- Bioslurping/Multiple –Phase Extraction
- Air Sparging / SVE
- Phytoremediation
- Adsorption
- Electrical separation
- Chemical treatment

Based on the available data and considering site-specific factors, phytoremediation, electrical separation and chemical treatment technologies were eliminated from consideration. The remaining technologies were further evaluated to address the site-specific contamination, particularly in the immediate area of the source area plumes. Table 6-1 provides a description of each LNAPL and/or lead removal technology considered, a summary of the advantages and disadvantages of each technology, the media which would be treated by the technology, the relative costs and remediation periods for each technology. Relative time and cost descriptions are included for specific technologies in Table 6-1 for the purpose of comparison with other technologies in the table. No attempt was made to determine the actual duration and cost to achieve cleanup goals at this time.

Based on the comparative analysis provided in Table 6-1, the SVE, bioslurping, bioventing/air sparging, and product skimming technologies or a combination of these and natural attenuation are the most applicable remedial alternatives for addressing the remedial objectives at the site. Based on simulated distillation analysis of a product sample from the site, approximately 64% of the product composition falls within the volatile range (carbon chain length up to 12). SVE, bioventing, or air sparging methods alone may remove the volatile components but would rely on biodegredation to break down the remaining heavier petroleum components. As a result, neither of these technologies alone would efficiently remediate the LNAPL. Mechanical removal of the LNAPL appears to be the best approach, in part, due to the limited area of LNAPL present. Bioslurping (multiphase extraction) or skimming would be the most effective means of product removal, remediating all components of the LNAPL.

TABLE 6-1

EVALUATION OF LNAPL AND/OR LEAD TREATMENT TECHNOLOGIES
FORMER NAVAL AUXILIARY LANDING FIELD-SITE 8
CHARLESTOWN, RHODE ISLAND

Technology	Description	Advantages	Disadvantages	Media Applicability	Relative Cost	Relative Remediation Period
No Action or Limited Action	No response actions initiated or response actions limited to periodic monitoring and/or land use restrictions.	Low cost.	Remediation limited to natural attenuation. Land use restrictions would limit future use and development options.	All	Lowest	Indefinite
Product Recovery Wells and Skimming Pumps	LNAPL is recovered via a series recovery wells; each equipped with a product level indicator and recovery pump. LNAPL is transmitted to a recovery tank via underground lines and disposed of off-site at a disposal/recovery facility. [A variation of this technology employs pumping groundwater to create a cone of depression in order to enhance product recovery].	A recovery pump system is relatively easy to design and install and implements standard engineering and construction techniques that are readily available. Recovery pump systems are also relatively easy to maintain. Implementation period could be < 90 days. [Creating a cone of depression would increase the LNAPL recovery rate and potentially the total volume of recovered LNAPL vs. no cone of depression. Some dissolved lead may be removed from the subsurface.].	LNAPL recovery rates would decrease within a short period after initiation and remain minimal for the duration of the remedial action due to a relatively small hydraulic gradient implied towards recovery wells. Additional recovery wells may need to be installed to recover LNAPL in minimally affected areas. Product recovery could be limited to < 20% total LNAPL present. [If groundwater is pumped to create a cone of depression, a separate groundwater treatment system or off-site disposal will be required].	LNAPL [Groundwater (limited)]	Low capital. Moderate operation and maintenance. [If groundwater is pumped, treatment costs will increase significantly.]	Indefinite
Soil Vapor Extraction (SVE)/ Bioventing	A SVE system consists of a series of wells screened in the vadose zone. A vacuum is applied to each well using one or multiple vacuum blowers. VOCs and some SVOCs present in LNAPL and adsorbed to soil particles volatilize as air moves through soil pore space. The introduction of oxygen to the vadose zone can also enhance any biological activity which can increase in-situ destruction of contaminants. Passive air injection vents can also be installed for biological activity enhancement and to minimize any preferential flow pathways. Vapors are collected and either discharged directly to the ambient air or treated prior to discharge. Bioventing is a variation in which air is injected into the vadose zone, but there is no active withdrawal of vapors. Remediation is	A SVE system is relatively easy to design and install and implements standard engineering and construction techniques which are readily available. SVE systems have historically been highly successful in the recovery of LNAPL. SVE systems also recover residual soil contamination. Any biological activity induced by SVE could decrease total contaminant air emissions and subsequently vapor treatment requirements. The advantage of bioventing is that no vapors or liquids are extracted, therefore no treatment of vapors or liquids is required.	SVE systems are constrained by low permeability soils. Residual amounts of groundwater and LNAPL may be removed by SVE and subsequently would require treatment or disposal. Preferential vapor flow pathways, such as utility trenches or high permeability soil layers, may "short circuit" vapor extraction, thereby limiting the area effected by SVE. SVE can also "mound" the groundwater and prevent LNAPL migration towards the wells. SVE is not effective in treating contaminated soils located below the water table. Removal of less volatile SVOCs would be predominately dependent on biodegradation stimulation. Inorganics, such as lead, which will not volatize, cannot be removed. Bioventing relies on biodegradation and can only attack LNAPL from the vapor/product interface resulting in very slow removal of	LNAPL Vadose zone soils. LNAPL Vadose zone soils.	Low capital. Moderate operation and maintenance costs. Low capital and O&M costs.	Estimated to be from 2 to 5 years. Relative remediation period of 3 to 8

TABLE 6-1

EVALUATION OF LNAPL AND/OR LEAD TREATMENT TECHNOLOGIES
FORMER NAVAL AUXILIARY LANDING FIELD-SITE 8
CHARLESTOWN, RHODE ISLAND

Technology	Description	Advantages	Disadvantages	Media Applicability	Relative Cost	Relative Remediation Period
	achieved by volatilization and stimulated biodegradation of contaminants in the vadose zone soil pore spaces.		LNAPL.			years.
Bioslurping/ Multiphase Extraction	Bioslurping utilizes a series of wells screened through the vadose zone and saturated zone interface. A vacuum is applied to the well through a suction tube placed in the well screen with the inlet at the LNAPL interval. LNAPL and groundwater are "slurped" through the suction tube by the induced vacuum. In addition, VOCs and some SVOCs present in LNAPL and groundwater and also adsorbed to soil particles volatilize as air moves through soil pore space. Some dissolved lead may be removed; if groundwater is "slurped" The introduction of oxygen to the vadose zone can also enhance biological activity which can increase in-situ destruction of contaminants. Each media recovered is treated as necessary.	Bioslurping wells can be easily modified to serve as standard SVE wells by raising the suction tube. Bioslurping allows for the removal of LNAPL, groundwater and soil vapors through the same well using a liquid ring pump. The cone of depression created would enhance product recovery. Soils located in the "smear" zone beneath the water table would be treated.	A significant amount of groundwater will be removed which will most likely require treatment. Low permeability soils can constrain vapor movement through the vadose zone. High permeability soils can result in the removal of mostly vapor, minimizing removal of liquids. Preferential vapor flow pathways, such as utility trenches or high permeability soil layers, may "short circuit" vapor extraction, thereby limiting effectiveness. Bioslurping is not effective in treating contaminated soils located below the water table. Removal of less volatile SVOCs would be predominately dependent on biodegradation stimulation.	LNAPL Vadose zone soils. Limited Groundwater	Moderate capital and high operation and maintenance costs.	Estimated to be from 3 mo. to 1 year for product removal. Is expected to be the shortest duration of all remediation options.
Air Sparging/SVE	An air sparging (AS) system consists of a series of air injection wells screened in the saturated zone beneath the interval of groundwater contamination. Air is injected through the air injection wells and rises through the groundwater to the vadose zone. Aeration of the contaminated zone stimulates aerobic biodegradation of soil and groundwater contaminants. In addition, volatile contaminants in the groundwater and adsorbed to soil particles volatilize into the air as it travels up into the vadose zone. A separate SVE system is required to remove the vapors from the vadose zone.	AS, combined with SVE, provides a greater mass removal rate and is more effective than SVE alone. In addition, this combination provides for the removal of dissolved contaminants in groundwater, in addition to the recovery of the volatile components in the LNAPL. Contaminated soils located below the water table would be treated, although at a slower rate than with multiple-phase extraction.	AS can oxidize metals in groundwater which can potentially clog the water-bearing soil. AS can "mound" the groundwater table and force LNAPL away from the effective radius of influence of the air injection wells. Low permeability soil layers can restrict the vertical flow of vapors through the saturated zone. Preferential flow pathways, such as utility trenches or high permeability soil layers, may "short-circuit" vapor recovery, thereby limiting vapor recovery.	LNAPL Groundwater Saturated and unsaturated soils.	Moderate capital, operation and maintenance.	Estimated to be 2 - 5 years.

TABLE 6-1

EVALUATION OF LNAPL AND/OR LEAD TREATMENT TECHNOLOGIES
FORMER NAVAL AUXILIARY LANDING FIELD-SITE 8
CHARLESTOWN, RHODE ISLAND

Technology	Description	Advantages	Disadvantages	Media Applicability	Relative Cost	Relative Remediation Period
Adsorption	An adsorption system consists of a large number of cubes within a tubular fish net enclosure to form an in-situ adsorption unit. Groundwater may be cycled through the unit to treat toxic metals. The system could also be used in combination with a pump and treat system.	Adsorption for lead removal can be an in-situ system.	Saturated units need to be frequently replaced and several units would need to be placed in-situ, therefore many additional wells would need to be placed. According the current data obtained, only bench-scale tests have been performed on lead reduction.	Groundwater	To be determined.	To be determined.

Bioslurping is also best suited for the low permeability soil conditions present in the saturated zone at this site. Skimming using product pumps would be significantly slower but would limit removal to LNAPL, thereby minimizing disposal costs for extracted wastes. Bioslurping would most effectively remove residual product from soil pores, whereas skimming would only recover free product susceptible to gravity flow. Subsequent to product removal, bioventing/air sparging would be suitable for enhancing biodegradation of the residual petroleum contamination plume. While the above technologies address the organic compounds, they would not be expected to have a significant effect on dissolved lead concentrations in groundwater. A risk assessment should be conducted to determine whether the risks due to lead are within acceptable limits, or whether a more aggressive remediation approach should be considered to mitigate the lead contamination.

The following remedial technology recommendations are made, pending evaluation of additional information to address data gaps and finalization of site-specific remedial objectives:

- Bioslurping is recommended to remove source area LNAPL at the water table and "smear zone". Product-phase lead would be removed in the LNAPL. Residual dissolved lead in the groundwater would be addressed through natural attenuation. Residual and dissolved petroleum hydrocarbons, including benzene, in groundwater may be addressed by bioventing and air sparging to accelerate natural attenuation.

- If significant risk from lead in groundwater exists, and if available data indicate that the dissolved lead in groundwater will not attenuate, then a more aggressive form of remediation may be employed such as groundwater extraction and treatment.

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

As a result of this Phase II investigation, the nature and extent of LNAPL, lead and petroleum compounds in groundwater and soil at the site have been largely defined. A network of monitor wells has been established at the site that adequately encompasses the plume associated with the site. An examination of the data presented in Sections 1 through 5 of this report leads to the following general conclusions as to nature and extent of environmental contamination observed at this site:

- An LNAPL plume covering a maximum area of approximately 4,400 ft^2 has been identified associated with the location of two former gasoline USTs on the western portion of the site. An area of sheen on groundwater has been identified on the eastern portion of the site in the vicinity of three former gasoline USTs in this area. The extent of contamination appears limited to the immediate area surrounding the former tanks, such that the central portion of the tank footprint area is largely unaffected. The LNAPL and dissolved contaminant plumes extend a limited distance south-southeast of the source.

- Analytical results indicate that the LNAPL and dissolved contamination are derived from leaded fuel, most likely gasoline. There is no indication of other waste streams associated with the site.

- Simulated distillation analysis results from the LNAPL indicated that approximately 64% of the product falls within the VOC range with the remaining 36% being heavier petroleum components.

- Soil data from this study do not indicate concentrations of organic compounds or lead above RIDEM residential direct exposure criteria or leachability criteria in the vadose zone or smear zone at the site. As a result, soil remediation is not warranted.

- The presence of LNAPL on the water table at the site exceeds the RIDEM Upper Concentration Limit for hazardous substances and will require remediation. Exceedances of RIDEM groundwater quality criteria for benzene and lead in groundwater were detected and will also need to be addressed.

- Bedrock groundwater at the site has not been impacted by on-site contamination.

7.2 RECOMMENDATIONS

The following recommendation are made based on review of existing data and evaluation of remedial technologies as discussed in Section 6 of this report:

- Sampling of groundwater from monitor wells CN13, GSA3, CN12 and GSA4 for total and dissolved lead analysis is recommended in order to confirm the dissolved lead concentrations in the source areas.

- A risk assessment should be conducted to determine whether a significant risk to human health and the environment from lead in groundwater exists at the site.

- Bioslurping is recommended to remove LNAPL at the water table interface and the "smear zone" soils. Bioventing/air sparging, institutional controls and natural attenuation are recommended for management of dissolved groundwater contamination. If natural attenuation of lead is determined to be ineffective, then groundwater extraction and treatment may be employed.

- It is recommended that one groundwater sample be collected for VOCs and dissolved lead from piezometer GSA-SG-1 in Little Nini Pond to characterize the sheen observed on groundwater.

SECTION 8

REFERENCES

8. REFERENCES

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